A REVIEW AND RECOMMENDATIONS OF THE MOST PROMISING TECHNOLOGIES FOR TREATING SLUDGES RESULTING FROM THE OILY WASTE TREATMENT PROCESS

by

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ABSTRACT

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Purpose

The U. S. Navy Petroleum Office (NAVPETOFF) is evaluating petroleum sludge disposal techniques that will conform to future, more stringent environmental regulations. This project will be conducted for NAVPETOFF to provide a list of current technologies and those promising technologies that offer a possible solution to the Navy's future hydrocarbon sludge disposal problems.

Procedure

Electronic data base searches, interviews with personnel currently using promising disposal techniques, reviews of current Federal Environmental Protection Regulations and California Hazardous Waste Control Laws, communications with manufacturers and personnel involved in hazardous waste remediation technologies, as well as manual literature searches were conducted to identify those technologies that offer the most promise to the Navy's future sludge disposal problems. The review concentrated on those technologies that have been or are being evaluated by the Environmental Protection Agency under current hazardous waste cleanup programs. The technologies were evaluated on their ability to successfully dispose of hydrocarbon sludges or the hazardous components of the sludges. Attempts were made to obtain as much information on those technologies considered promising, such as: manufacturer of technology, costs, test verification of technology, general description of procedure, and results.

Conclusions

Current technologies are available, or are under development that can successfully dispose of Navy fuel facility oily wastes. Future costs of disposal using new technologies, or by existing methods, can be expected to increase due to the impact of more stringent environmental regulations. Waste minimization practices in operations can reduce waste quantities. Analyses of future disposal options should include factors such as: elevated future costs, liability that current disposal methods or new technologies

places on the government in the future, level of detoxification of the disposal method, and the impact of hazardous waste disposal on current and future fuel facility operations. Future analyses and decisions based on the analyses will require an accurate estimate of hazardous waste generated at Navy Fuel Facilities, this information is not currently available.

Recommendations

The Navy while continuing the current method of disposal, due to its lower costs and availability, should evaluate future disposal options based on long-term payback. Environmental agencies at both the state and federal level, and research facilities such as the Naval Civil Engineering Laboratory should be continually queried on new hazardous waste disposal technologies and their suitability for use on wastes at Navy fuel facilities. Site tests on those technologies that show promise should be encouraged.

Information concerning hazardous waste disposed of by Navy Fuel Facilities should be collected via addition of the requirment on existing annual reports.

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DISCLAIMER

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I. INTRODUCTION

I-A. Purpose of Project

This project involves a review and analysis of recently published literature on the technologies currently available or under development for the disposal of sludges which result from the oily waste treatment process. This project responds to a suggestion by the Navy Petroleum Office for a search of literature on this particular subject. Information from this project will be used as a means of identifying techniques that may warrant further study in order to determine potential future oily waste sludge disposal methods.

I-B. Nature of Reviews

Each piece of literature reviewed was evaluated based on the following questions:

- Is the literature current, i.e. within three years? If so, the technology probably has probably been initiated as a result of the more recent changes in the environmental regulations.

- Is the technology described applicable to the particular types of sludges found in the Navy's oily waste treatment process?

- Has the technology been evaluated in actual field conditions by a state, or federal environmental regulatory body?

- Does the technology offer an ultimate disposal option, or if not, what further processing is required to dispose of the waste streams generated?

- What are the advantages, or disadvantages of the technology?

- Where are sources of information that may be useful to the Navy or other personnel interested in new hazardous waste disposal?

I-C. Study approach

I-C-1. Methods of literature and information search employed

The methods, which provided literature addressing the above questions, fall into five categories. These categories are summarized below in decreasing order of the volume of references produced.

I-C-1-a. Index searches

Indexes such as Applied Science & Technology Index, The Environmental Index, General Science Index, and Environment Abstracts Annual were manually searched by subject category and keywords to obtain literature meaningful to the study. Abstracts from the indexes provided a means to preview and sort out numerous pieces of irrelevant information. A listing of common periodicals was developed from the various indexes. Each of the periodical issues from the past three years was manually reviewed to uncover relevant literature. Each piece of literature discovered as relevant to the study was reviewed for further references. Each piece of retained literature was evaluated to determine if it answered the questions of section I-B.

I-C-1-b. Interviews

Interviews were conducted both on location and via telephone. Navy fuel personnel, Navy technical personnel, federal and state regulators and industry representatives were contacted in order to

establish current disposal methods, standard operating procedures, environmental regulations, or locate more information on a technology. During interviews with each of the personnel I continually asked for their assistance in identifying further relevant information, or other points of contact. Literature and information provided by this means was evaluated on its ability to answer the questions of section I-B.

I-C-1-c. Electronic data base searches

A keyword search of the Alternative Treatment Technology Information Center (ATTIC) database was conducted for me by a Superfund Innovative Technology Evaluation (SITE) coordinator. The SITE coordinator was available via a (800) phone number provided by the Environmental Protection Agency's (EPA) Region VII office in Kansas City. The ATTIC system developed by the U.S. EPA is currently composed of six databases, the most important of which is the ATTIC Database (Dorris, 1989). This database contains technical information on alternative technologies for hazardous waste remediation in the form of abstracts from the SITE Program (Dorris, 1989).

At the beginning of the project I conducted a keyword search on the ABI Inform database at Watson Library on the campus of the University of Kansas. The ABI Inform database is composed of five years of published articles in abstract form from numerous magazines, journals, and newspapers. The database proved to be a good starting point and provided numerous abstracts concerning Hazardous Waste Technologies. Literature provided as a result of

the electronic database searches was evaluated based on the answers to questions of section I-B.

I-C-1-d. Previous work on oily wastes in the Navy

Previous works on oily waste treatment and sludge handling were of particular importance to the review. Of special value was a recent thesis on bioremediation as a treatment source for petroleum wastes (Lubbers, 1989). Numerous potential candidates of information were obtained from bibliographic data generated by this work. Discussions with its author enabled me to sort out data not relevant to the study. Another valuable source of information on the Navy's oily wastes was the Naval Civil Engineering Laboratory (NCEL) in Port Hueneme, California. NCEL's work on oily waste was initially discovered by Mr. Norm Schmokel, of the Navy Petroleum Office, who forwarded a copy of NAVFAC P-916 for review. Contact with NCEL proved very rewarding as it was discovered that numerous studies had been performed on the inventories and classification of the oily sludges at Navy Fuel Terminals. Ms. Leslie A. Karr, co-author of NAVFAC P-916, was very helpful in providing numerous documents on her studies of the Navy's oily wastes.

I-C-1-e. Questionnaires/Written requests for information

Questionnaires were prepared and forwarded to Director's of three of the Navy's major Fuel Terminals located on the west coast. Correspondence with the terminals was recommended at the onset of the study by the Navy Petroleum Office in order to understand the problems currently being experienced in the field (E.W. Pinion, personal communication, Jan. 11, 1990). The questionnaires were

forwarded to obtain information concerning procedures currently being used in the disposal of oily waste sludges, future plans for disposal of sludges, and to quantify the amount of oily waste sludges handled at these particular locations.

I-C-2. Scope of literature on promising technologies for treating sludges

There are numerous publications and articles describing new technologies for hazardous waste disposal. A single keyword search using "waste technology" produced 88 candidate articles published since 1986. The ATTIC database contained information from over 900 technical documents and reports on alternative treatment methods for hazardous waste disposal, while the National Technical Information Service (NTIS) listed 116 published articles in one of their "packaged" database searches for "hazardous waste disposal".

I-C-3. Published literature

In order to reduce the information to what I considered the most relevant sources of data for this report, the following criteria were placed on published literature discovered by the searches described above.

- Articles and information published since 1986 were weighted higher in determining relevancy.

Exceptions made to this criterion were articles or information from environmental regulatory bodies (federal and state EPA's) which referenced technologies in proven field tests on oily waste (EPA, 1986), or where a published work proved to offer significant background information on the specific oily wastes

being studied ("User's Guide", 1985).

- The document must report a technology that had either been field demonstrated with favorable results, or that was selected for testing as part of a state, or federal "Emerging Technology Program".

- The technology had to have been tested on oily waste sludges .

These limits served two important purposes:

- First, the most significant hazardous waste disposal regulations were imposed by the Hazardous and Solid Waste Amendments (HSWA) of 1984. Congressional deadlines imposed on EPA and those regulated under the regulations effectively reduced and continue to reduce disposal options (Olschewsky & Megna, 1988). As standards imposed became more stringent and more disposal options were included in hazardous waste guidelines, incentives fostered the development of hazardous waste treatment technologies. In 1986 EPA instituted the Emerging Technology Program as part of the SITE Program to foster further developments and to evaluate hazardous waste treatment technologies (Bates, Herrmann, and Sanning, 1989). I have concentrated on the technologies in these programs, as I feel they offer the most promise. Disposal technologies being evaluated in the programs are being subjected to a standardized testing procedure by EPA, whose approval will almost certainly lead to successful licensing and certification of the particular technology. In the Emerging Technology Program, EPA has provided at least partial funding to technologies in the developmental phase

(Bates et al., 1989). I felt this represented a sign of confidence in the particular technology by the regulatory body, and felt it deserved consideration as a viable disposal technology.

- Second, the limits allowed me to focus on those technologies specifically applicable to petroleum sludges comparable to those existing at Navy fuel facilities. By doing this I minimized the chances of reviewing a technique that was not pertinent, thus saving countless hours of unnecessary reviews of of irrelevant data.

When these conditions were imposed on the candidate literature, the number of documents considered pertinent was significantly reduced. These documents serve as the foundation of this study.

II. BACKGROUND

II-A. Sources of Oily Waste Sludges at Navy Fuel Terminals

Navy fuel facilities handle a number of refined petroleum products ranging from in rare cases heavier bunker fuels to the more common products: marine diesel, jet fuels and gasolines. The facilities accumulate oily waste sludges in all stages of the distribution process which include issuing and receiving products to and from its military customers, or receipt operations via pipeline, marine tankers or barges. Ten generic sludges produced at naval installations were identified and characterized by the Naval Civil Engineering Laboratory ("User's Guide", 1985). The source of sludges included:

- gravity separator bottoms
- gravity separator interface
- dissolved aeration flotators
- oil recovery units
- oil sumps
- dewatering processes
- wastewater impoundments
- American Petroleum Institute (API) and coalescer separators
- waste transportation vessels
- fuel tanks

The sludges produced within each source were found to have "distinct and characteristic physical, chemical, and toxicological

properties, irrespective of their geographical origin" ("User's Guide", 1985). For the purpose of this study, the Navy Fuel Terminals were divided into two general categories based upon facilities and source streams of oily waste sludges:

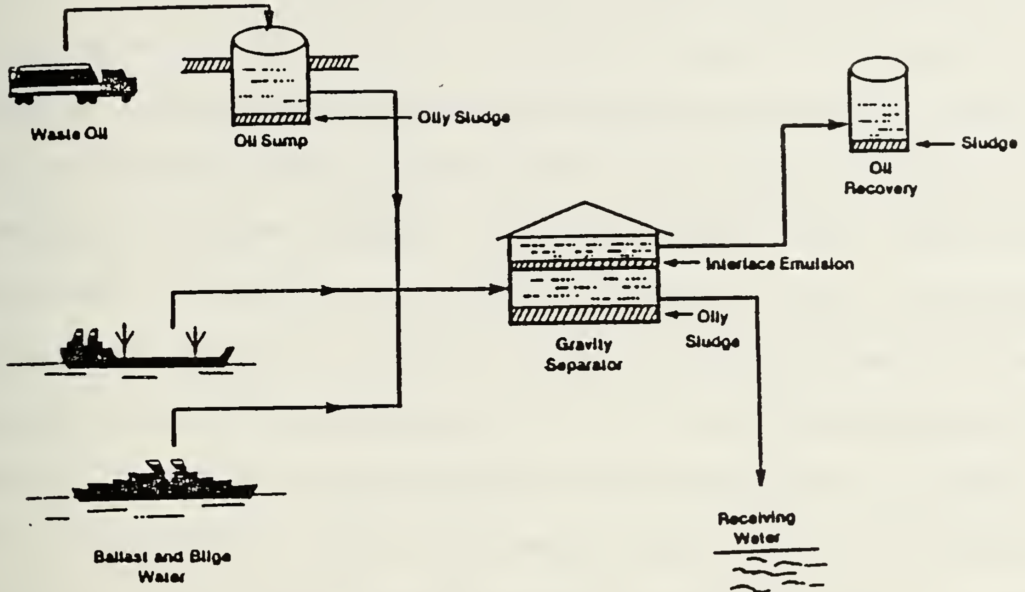
- Facilities without waste water treatment plants
- Facilities with waste water treatment plants

The categorization of the fuel facilities in this manner only serves to recognize those facilities with additional oily waste treatment capabilities. Terminals in either category produces varying quantities of oily waste from basically the same sources. These oily wastes are processed at the terminals into usable products, oily wastewater streams, and of particular concern to this study, oily sludges. An estimated annual production of oily waste sludges at Navy installations was determined in a report prepared for NCEL in 1984 (deMonsabert, 1984). Information from this study appears in Table 1.

II-A-1. Oily waste sludges from facilities without waste water treatment plants

In general, most of the fuel terminals operated by the Navy throughout the world are included in this group. Figure 1 shows the equipment involved in this process as well as the sources of fuel requiring treatment. Equipment at each location generally includes oil sumps, gravity separators, API separators, with the water either discharged into the environment or sewer lines. In the course of this study and based upon my experience in the field I do not know of a fuel facility able to discharge directly into a

Figure 1. Operation diagram (Facilities without waste water treatment plants).



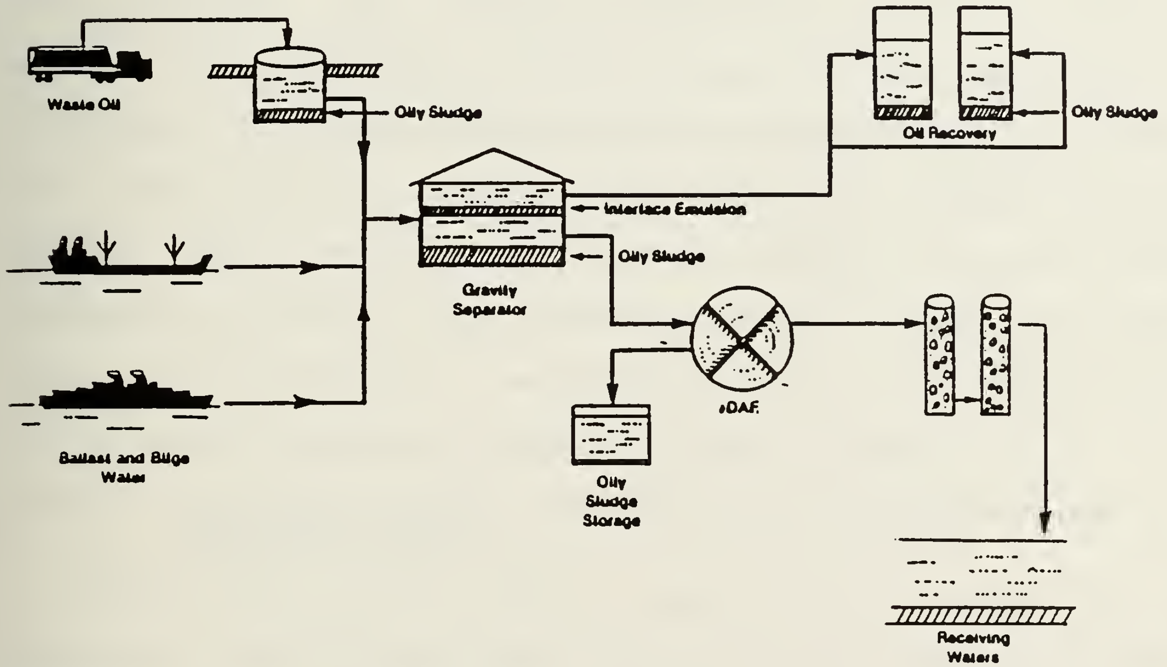


Figure 2. Operation diagram (Facilities with waste water treatment plants).

Adapted from NAVFAC P-916 (1985)

municipal sewage treatment system. The primary reasons for this are location of facilities, or lack of treatment capacity of the municipal sewage treatment facility serving the area. Due to these reasons most facilities operate under National Pollutant Discharge Elimination System (NPDES) permits which set limits on the pollutants of effluent directly discharged into environmental waters. The permit is a legally enforceable agreement between the regulatory agency (EPA/State) and the direct dischargers on the quality of effluent released into receiving waters ("NPDES Self-Monitoring System", 1985). The water quality of the effluent prior to discharge into environmental waters is another major concern for fuel facilities. The effluent disposal was considered as being separate from the sludge treatment and not within the context of this study. Oily waste sludges generated within facilities without waste water treatment plants were considered primary treatment sludges ("User's Guide", 1985). These sludges are mainly due to separation by gravity of the contaminants in oil sumps, oily waste tanks, gravity separators, and API separators. A characterization of the primary treatment sludges is found in Table 2.

II-A-2. Oily waste sludges from facilities with waste water treatment plants

Only three of the Navy's larger fuel terminals in the continental United States have oily waste water treatment plants. Equipment typically used in this process (Figure 2) include oily sumps, gravity separators, API separators, oil recovery units (cookers), aeration, floc, and dissolved aeration flotator (DAF) tanks, as well as sand and carbon column filters. Sludges

accumulated at the facilities are from products of primary treatment (gravity separation), secondary treatment processes (filtration, chemical addition), and sludges from the "cookers" used in the reclamation process. Secondary treatment sludges evaluated by NCEL were those produced in DAF, API, oil recovery units, and coalescer separators ("User's Guide", 1985). The secondary treatment sludges evaluated by NCEL were "reduced in free oil, and toxic substances contents as the result of the removal of sludges in the primary treatment units" ("User's Guide", 1985). Table 2 summarizes the characteristics of oily sludges accumulated from the secondary treatment process.

II-A-3. General characterization of Navy oily sludges

A study of 120 Navy-generated oily sludges from ten of the most prominent installations treating oily wastewaters was conducted by Lysyj and Karr in 1984 and found:

- "All oily sludge samples contained toxic chemical substances."
- "All oily sludge samples exhibited toxic properties" (toxicity determination was made by the Beckman Instruments Microtox Toxicity Analyzer).
- "The principal contributors to sludge toxicity are PAH, phenols, and heavy metals." (Polynuclear aromatic hydrocarbons (PAH) - a class of organic compounds that are usually characterized by the presence of two or more fused aromatic rings. Some of these compounds have been identified

as carcinogens.)

- "High concentrations of free oil and PAH were found in sludges from primary treatment units; lower concentrations were found in sludges from secondary treatment units."
- "Oily sludges from primary treatment units are generally more toxic than oily sludge from secondary treatment units."
- "The concentration of PAH is directly proportional to the concentration of free oil."
- "The concentration of phenols was directly proportional to the concentration of dissolved oil."

II-B. Current oily waste disposal practices

In order to determine the current disposal methods being used at the Navy fuel terminals I forwarded questionnaires to the three west coast terminal directors, and personally corresponded with the assistant fuel officer, LCDR Ken Bitter at NSC Norfolk (personal communication, 1 March 1990). Each of the facilities used outside contractors to dispose of oily waste sludges. The waste was analyzed in all cases prior to disposal in order to ensure that hazardous wastes were properly identified for disposal. The use of outside contractors by the Navy for waste disposal was also cited as the main disposal method in a previous study for NCEL (deMonsabert, 1984)

Table 1. Oily Sludge Production of Naval Installations

	Volume of Water Processed		Annual Volume (gal) Oily Sludge Produced	
Facility	GPD[a] (000's)	GPY[b] (000's)	Est Based on Reported Averages (000's)	Est Based on Manchester Case (000's)
Fuel Depot, Craney Island, VA	100	25,000	250	625
NSC, Point Loma, CA	50	12,500	125	312.5
NSC Pearl Harbor, HI	40	10,000	100	250
NAVSTA, Mayport, FL	35	8,750	87.6	219
NSC, Manchester, WA	9	2,250	22.6	56

[a]GPD = gallons per day

[b]GPY = gallons per year

Source: Adapted from deMonsabert (1984)

Table 2. Characteristics of Navy Oily Sludges

CHARACTERISTIC	PRIMARY TREATMENT SLUDGES	SECONDARY TREATMENT SLUDGES
Free oil content	20%	2%
Inorganic solids	5%	2%
Organic solids	3-5%	4%
Dissolved oil	1%	1%
* PAH's	6000 ppm	300 ppm
Phenols	500 ppm	300 ppm
** Heavy metals	400 ppm	150 ppm

Primary Treatment - sludges from oil sumps, oily waste storage tanks, gravity separators

Secondary Treatment - sludges from DAF, API, and coalescer separators

* Polynuclear Aromatic Hydrocarbons

** Heavy Metals included Cr, Cu, Pb, Ni, Zn

Source: Adapted from NAVFAC P-916 (1985)

II.-C. Environmental regulation of oily waste disposal

Minimum standards for hazardous waste disposal are promulgated by the Federal EPA. The two principal laws that establish control of hazardous waste are the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation & Liability Act (CERCLA or Superfund). RCRA, first passed in 1976 and strengthened by the Hazardous & Solid Waste Amendments (HSWA) of 1984 is "designed to ensure that hazardous chemicals are not discarded in such a way as to cause harm to human health or the environment" (Hanson, 1989).

It provides for "cradle to grave" management for those chemicals listed in the law as hazardous. Currently there are more than 450 chemical wastes listed (Hanson, 1989). Specific permits are required for facilities treating, storing, or disposing of hazardous waste, and the laws provide for a manifest-tracking system to ensure wastes are handled properly (Hanson, 1989). Superfund, on the other hand, is designed to remedy environmental problems from the past. Under this program old hazardous waste sites, many abandoned, are currently being cleaned up. The cost of cleaning up the sites is assessed to those responsible, if liability can be ascertained. If not, the cleanup is paid from funds available under Superfund. The funds are the result of taxes applied to basic chemicals, and fines collected from those responsible of violations under the act.

The main emphasis of this review will be to review a selected number of future technologies and their ability to dispose of oily

wastes within the disposal requirements promulgated under RCRA.

II-C-1. Federal Regulation by EPA

II-C-1-a. Hazardous waste determination

The initial concern of an activity in waste disposal is to determine if its oily waste sludge is hazardous. Figures 3 and 4 (reprinted from CFR Title 40, Part 260 Appendix 1) are flowcharts which can assist in this determination. The actual determination is not as simple as it appears. In order to determine if the waste is hazardous, an activity must first determine if the particular waste is considered a solid waste. RCRA defines hazardous wastes in terms of solid waste. Consequently, if a waste is not a solid waste it cannot be a hazardous waste. The solid waste definition found in CFR Title 40, Part 261, section 2 starts the reader winding through the various exclusions, and variances provided in the regulations. It is easily understood how interpretations of this section between the Environmental Regions, and states can vary. A thorough understanding and use of the regulations can lead to tremendous savings on disposal costs. Rogers (Rogers, 1989) described how Williams Pipeline Co., Tulsa, Oklahoma successfully modified their oily waste treatment process to avoid classifying tank bottom material as a solid waste. If the waste is considered a solid waste, it must be further evaluated to determine if it is a hazardous waste. It can be considered a hazardous waste by its appearance on one of four lists provided in CFR Title 40 CFR 261, section 3, by the inherent characteristics of the waste, or by being a mixture containing a hazardous waste. The four lists are

broken down into waste from nonspecific sources ("F" list), waste from specific sources ("K" list), acutely toxic waste ("P" list) and toxic waste ("T" waste) (Olschewsky, Megna, 1988). The general characteristics which may also lead to classification of the waste as hazardous are:

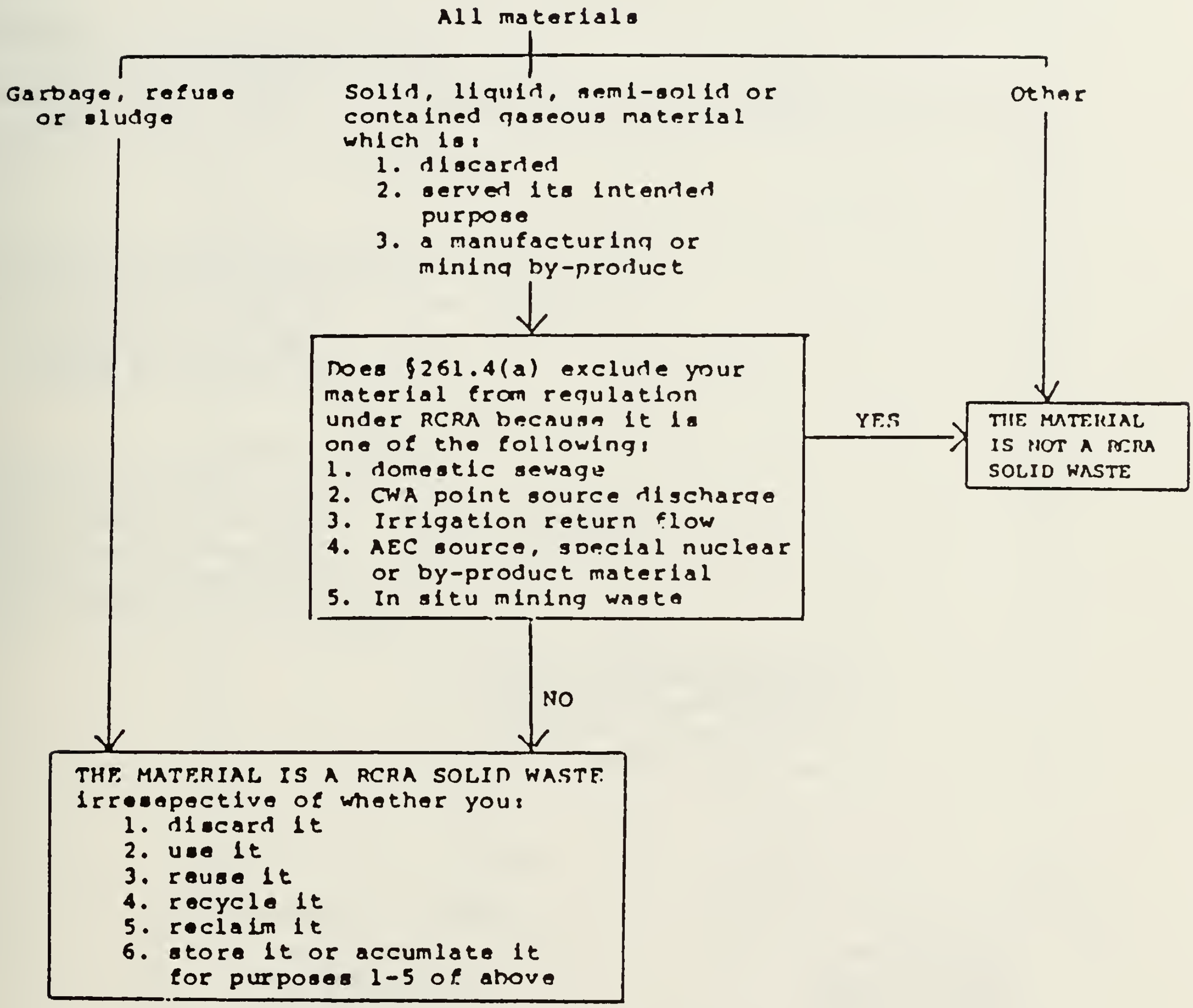
- Ignitable, basically if the material has a flashpoint less than 140 degrees fahrenheit, it is ignitable and assigned a hazard code (I).
- Corrosive, if the waste has a pH less than 2 or greater than 12.5, or if the waste corrodes stainless steel at a certain rate; it is corrosive and assigned a hazard code (C).
- Reactive, if it is unstable and produces toxic materials, or is a cyanide or sulfide bearing waste which generates toxic gases or fumes. If it meets one of the criteria it is reactive and assigned a hazard code (R).
- EP Toxic, if the waste is tested for the characteristics of EP Toxicity and fails by exceeding the maximum concentration of contaminants, or other listed tests it is assigned a hazard code of (E).

In a discussion with Mr. Wheeler, EPA Region VII, he stated that toxicity levels will be based on 25 organic constituents beginning in May 1990, an increase from the current level of eight (personal communication, 16 Feb. 1990).

For the purposes of this review and based upon the prior study of Navy oily waste sludges (Lyzyj & Karr, 1984) wastes will be considered hazardous in order to evaluate technologies capable of

Figure 3

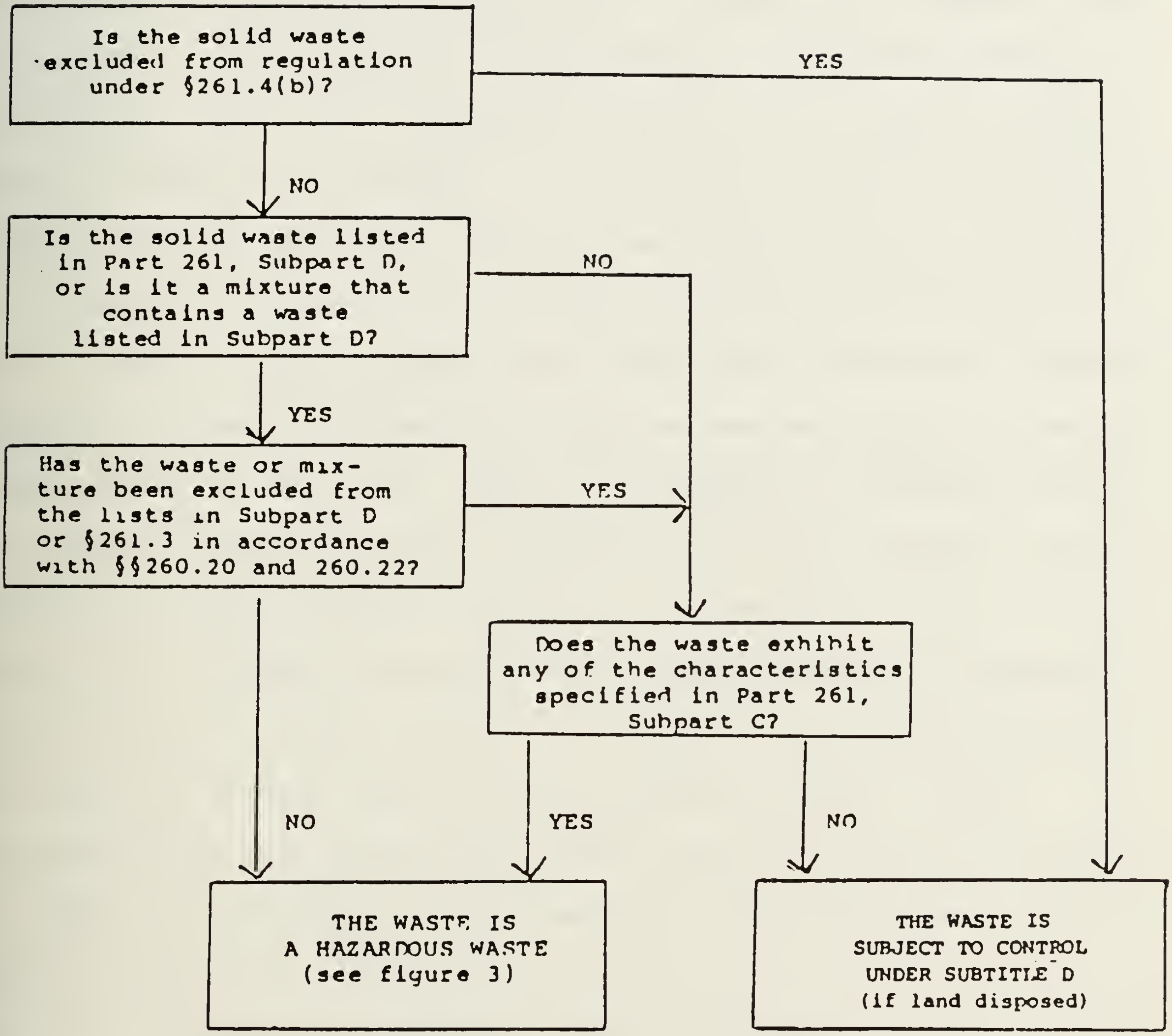
DEFINITION OF A SOLID WASTE



Adapted from CFR Title 40, Part 260, App. 1

Figure 4

DEFINITION OF A HAZARDOUS WASTE



Adapted from CFR Title 40, Part 260, App. 1

disposal. In reality each "batch" of sludge is evaluated and disposed of based upon the results of the analysis. The determination of a sludge being hazardous is not a simple process due to the complexity of the regulations. The analysis and appropriate disposition of each batch of waste could save the Navy significantly over periods of time. Commercial companies use various means to keep their sludges from being labelled, hazardous. The Williams Pipe Line company's approach to sludge disposal (Rogers, 1989) is an example. I visited the Williams Pipeline Company facility in Kansas City, KS, and discussed the operations and the Rogers' article with the Manager of Process Technology, Mr. David Young. The Kansas City facility processes sludges transported from the 8,500 mile pipeline system; products handled include gasoline, jet fuel, fuel oil, and crude oil (Rogers, 1989). The company separates usable products from the sludges using a filter press; the effluent water is discharged to the City of Kansas City's sewage system and filter cake residue is disposed in a local landfill (Rogers, 1989). The filter cakes have been tested and certified nonhazardous by EPA standards (Rogers, 1989). Mr. Young mentioned that RCRA changes were pending that would increase the number of constituents listed as toxic, which may cause them to modify the existing operation.

II-C-1-b. Disposal limitations imposed by RCRA

The Hazardous and Solid Waste Amendments signed into law on Nov. 8, 1984 included many "hammer laws" which forced EPA to promulgate regulations within a certain timeframe (Olschewsky &

Hegna, 1988). If regulations were not promulgated the law went into effect as written by Congress. The laws, as written, showed a strong bias against land disposal of hazardous waste. "Hammer provisions" concerning oily waste disposal which are now part of the laws are:

- As of May 5, 1985 bulk or non-containerized liquids were no longer allowed to be disposed of in landfills (CFR Title 40 Part 264, section 314).

- Effective Nov. 8, 1985 all liquids were banned from disposal in landfills, unless the operators and owners certified it as the only alternative and that the liquids would not contaminate any source of underground drinking water (CFR Title 40, Part 264, section 314).

- Effective Nov. 8, 1986 certain spent halogenated and non-halogenated solvents were banned from land disposal (CFR Title 40, Part 268, section 30).

- Effective July 8, 1987 the "California list wastes" were banned from land disposal. This included liquid hazardous wastes with a pH less or equal to 2.0, liquid hazardous waste containing polychlorinated biphenyls (PCBs), or liquid hazardous waste halogenated organic compounds (HOCs) containing in total concentration greater than or equal to 1,000 mg/l and less than 10,000 mg/l HOCs (CFR Title 40, Part 268, section 32).

The above cited regulations are but a few of the many imposed on the land disposal of hazardous wastes. An option for the producer

of hazardous waste determined to dispose of material via land disposal is to pretreat the waste initially rendering it nonhazardous. In any event, the limitations imposed by RCRA will prohibit certain waste from disposal by this method.

Incineration, the second largest means of sludge disposal is also expected to be effected by changes to the emissions standards for carbon monoxide and metals (Goldbaum, Rotman, Tantillo, 1989). The standards would set tougher emissions standards and require permitting of industrial boilers, currently used by an estimated 1000 facilities to burn their hazardous wastes (Goldbaum, et al., 1989). Though considered tough the proposed regulations are relatively easy compared to other forms of disposal, such as land application. A Black & Veatch study (cited in Morse, 1989) of proposed regulations by various disposal options indicated eight contaminants in the sludges would be required to be monitored if wastes were incinerated, whereas regulations proposed for land application would require monitoring of over 20 contaminants (Morse, 1989).

RCRA regulations were imposed to promote environmentally sound disposal methods, maximize reuse of recoverable resources and foster resource conservation. Regulations imposed will not only increase the number of contaminants considered hazardous, but will limit existing disposal possibilities thereby effectively increasing the cost of disposing of hazardous waste.

II-C-2. RCRA and State administered environmental programs

RCRA was designed by Congress to be administered by the states

with only minimal oversight by the Federal Government. In order to obtain responsibility for the Subtitle C program the States must develop a hazardous waste program and have it approved by EPA (Environmental Protection Agency [EPA], 1986). The states were given two options for assuming responsibility, either an interim or final authorization (EPA, 1986). The interim authorization allows the state to develop and implement a hazardous waste program, but the program is not considered as stringent as the Federal program. The final authorization signifies the state program is at least as stringent as the Federal enacted one (EPA, 1986). Of particular concern to the Navy are those states where hazardous waste laws are more stringent than EPA's. California is one of the states of primary concern to the Navy, because of the location of two major fuel terminals. The facilities operating in California must abide by the hazardous waste laws of the state, as well as the local governments.

III. NEW TECHNOLOGIES TO MEET FUTURE HAZARDOUS WASTE DISPOSAL REQUIREMENTS

III-A. -Impetus for new treatment and disposal technologies

The regulations imposed by Superfund and RCRA have generated increased interest in new technologies for hazardous waste treatment and disposal. Owners of waste sites faced with site cleanups are interested in cheaper and long term remedies for their hazardous waste problems. Entrepreneurs realize the opportunity and economic benefits of a tested commercial treatment process. Entrepreneurs, as well as the government realize that despite waste minimization efforts such as, recycling and process modification, waste volumes will continue to grow. Freedonia Group, a consulting firm in Cleveland, completed an in depth study of the future prospects for the waste industry. It concluded the industry will be a $20 billion service and product business in 1993 (Hansen, et al). Growth estimates from this study are provided in Table 3. An important catalyst in the evolution toward new innovative technologies has been EPA's Superfund Innovative Technology Evaluation program (SITE) (Rubin, Kemezis, and Kosowatz, 1989). Congress understood that few technologies were tested and available to meet the demand of the new regulations. The SITE program, initiated in 1986, was a way to get responsible contractors and corporations to venture into research for innovative technologies to solve this problems. EPA's participation in the program was seen as a way to accelerate the development of the technologies. The SITE Program basically consists of two separate programs: the Demonstration Program, and the Emerging Technologies Program.

Table 3.

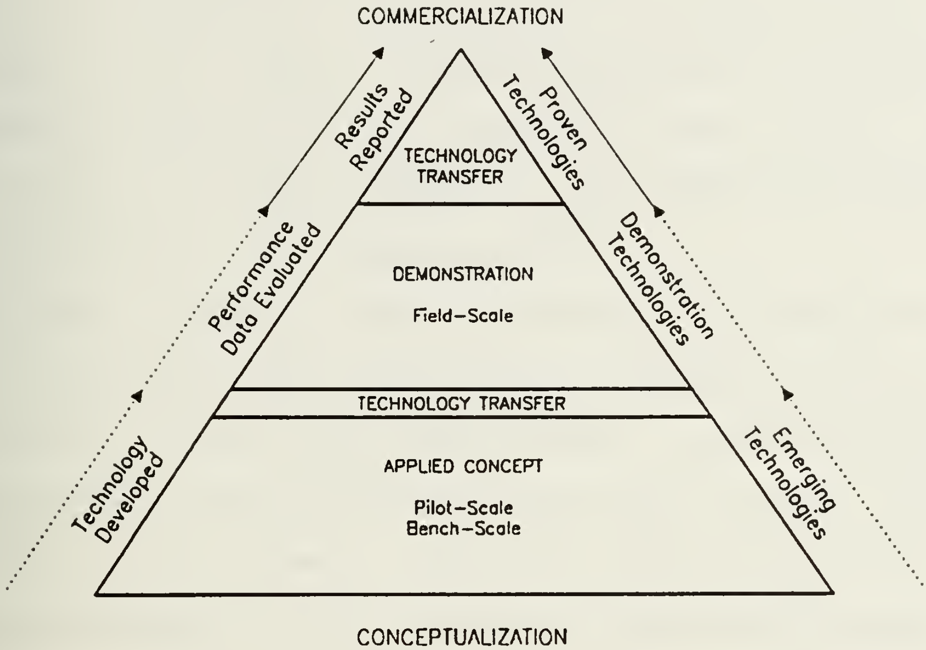
Waste volume will grow despite reduction efforts

Millions of tons	1977	1988	1993	2000	Average Annual growth 1977-88	1988-93
TOTAL BY TYPE OF WASTE	131	291	380	510	7.5%	5.5%
Heavy Metals	51	114	149	196	7.6	5.5
Organic chemicals	42	100	132	180	8.2	5.7
Petroleum Derived	16	33	44	60	6.8	5.9
Inorganic chemicals	17	35	43	55	6.8	4.2
Other Hazardous Waste	5	9	13	19	5.5	7.6
BY METHOD OF DISPOSAL						
LANDFILL/ SURFACE IMPOUNDMENT	12	200	225	165	29.1	2.4
STABILIZATION /TREATMENT	2	13	50	150	18.5	30.9
INCINERATION	neg	15	35	95	---	18.5
RESOURCE RECOVERY	2	12	30	75	17.7	20.1
DEEP WELL INJECTION	5	14	15	10	9.8	1.4
ILLEGAL DISPOSAL	110	35	20	5	-9.9	-10.6
OTHER	neg	2	5	10	----	20.1

neg= negligible

Adapted from Freedonia Group (Hansen, 1989)

Figure 5



Development of Alternative and Innovotive Technologies

Adapted from the Environmental Protection Agency (EPA, 1989)

Figure 5, shows the interrelationship between the two programs. The Demonstration Program places emphasis on technologies which have been developed. Successful field demonstrations of these technologies is expected to lead to commercialization (Bates, et al., 1989). As of November 1989 the Demonstration Program had 37 active participants, divided into five categories: thermal, biological, chemical, physical, and solidification/stabilization (EPA, 1989). The second program, the Emerging Technology Program, takes technologies that have been successfully "bench-or laboratory-scale" tested by the private sector and encourages

urther development. The goal is to ensure an availability of ermanent, cost-effective technologies for demonstration in the ield (Bates, et al., 1989). Financial assistance is available up o $150,000 per year for up to two years (Bates, et al., 1989). here have been 24 (+E03 selectees) participants selected under our solicitations as of 5 January 1990.

The SITE program has been responsible for accelerating the leanup of Superfund sites and increasing the participation of the rivate sector in developing technologies, but many participants nd observers say the driving force has been the RCRA "land ban" ules (Rubin, et al., 1989). Since 1986, EPA has banned the land isposal of hundreds of toxic substances without pretreatment. The imitations placed on land disposal and the addition of onstituents to the hazardous waste lists are generally considered he real impetus behind the increasing interests in new treatment nd disposal technologies. Future environmental regulations can be xpected to be more stringent and place further limitations on isposal options. The increasing amount of hazardous wastes, fewer ocations to store or treat them, and liability questions are a few f the concerns of the generators of the hazardous waste. echnologies, such as those under development in the SITE program ffer possible solutions to future treatment and disposal problems.

II-B. Selection methodology for Technologies

Numerous technologies are being evaluated under the SITE rogram. For the purposes of this paper, technologies selected as

"promising" were those that had been successfully tested on oily waste sludges with similar characteristics. Table 2, identified characteristics of oily waste sludges found in Navy fuel terminals. A source used to determine the suitability of using a technology on oily waste sludges was the "Technology Screening Guide for Treatment of CERCLA Soils and Sludges" (EPA, 1988). The "Guide" provides a screening methodology for evaluating alternative treatment technologies at Superfund sites (EPA, 1988). The "Waste Technology Matrix: Sludges" from the guide located in Appendix A was consulted for applicability of particular technologies to waste sludges. Technologies selected as "promising" were divided into four general categories: biological, physical and chemical, solidification/stabilization, and thermal. Discussion of each selected technology will address the following areas:

1. Description and Operation of the Technology
2. Advantages/Disadvantages
3. Information on prior/scheduled testing
4. Cost data (if available)

IV. INNOVATIVE TECHNOLOGIES FOR OILY WASTE DISPOSAL

IV-A. Biological Treatment Technologies

Biological treatment processes, such as landfarming, for degradation of petroleum sludges have been used by refiners since the 1950's. The Navy has also used "sludge farming" to dispose of sludges resulting from various operations, such as tank cleaning. The disposal of organic wastes by landfarming in environmentally modified facilities was lauded as late as 1989 (Wimberley, 1989). It should be of no surprise that new technologies are looking at microorganisms and their ability to degrade wastes. Bioremediation, the use of bacteria, fungi, and other natural organisms to break down organic waste has been used as the basis of a number of innovative technologies (Rubin et al., 1989). Proponents of the process stress its lower costs, compared to technologies such as incineration, and its ability to provide permanent solutions when disposing of waste. Characteristics which must be considered prior to selecting bioremediation as a hazardous waste disposal option are provided in Table 4.

There are two major classes of biological treatment. The classes are, aerobic (with oxygen), and anaerobic (without oxygen). In aerobic treatment, microorganisms take in oxygen and organic molecules and release carbon dioxide, water, ammonia, nitrate, and sulfate. High dissolved oxygen concentrations and large microorganism populations lead to rapid degradation. Anaerobic treatments take place in the absence of oxygen. Common products of

anaerobic treatment are methane, hydrogen sulfide, organic acids, and carbon dioxide. Anaerobic processes may also produce unpleasant odors. Aerobic degradation technologies are more common than anaerobic, better understood and more easily cultured (Potter et al., 1986).

Biological treatment technologies though still not used as a primary remedy for hazardous waste site cleanup are beginning to gain greater acceptance by EPA and other regulatory bodies. EPA recently approved a bioremediation technology demonstrated by ENSR and Celgene corporations for a petrochemical sludge site. This was the first time EPA had approved bioremediation for a Superfund site (Vervalin, 1989). California, noted for its tough environmental regulations, announced the successful completion of the state's first approved bioremediation project (Vervalin, 1989). The project, a service station site involving a 1,000 gallon gasoline spill, was successfully remediated over a one year period. Biodegradation technologies currently being tested, which may offer potential oily waste sludge disposal options, fall into two general categories: slurry-phase, and solid-phase treatments. Two technologies selected to participate in the SITE program, though currently not demonstrated will be discussed.

IV-A-1. Slurry-Phase Treatment

IV-A-1-a. Description and operation of the technology

This technology treats soils or sludges in a large mobile bioreactor. The system maintains intimate mixing and contact of the microorganisms with the hazardous compounds, promoting

TABLE 4. TECHNOLOGY SUMMARY

WASTE TYPE: Soils and Sludges
TECHNOLOGY: Biodegradation

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Variable waste composition	Inconsistent biodegradation caused by variation in biological activity.	Waste composition
Water solubility	Contaminants with low solubility are harder to biodegrade.	Solubility
Biodegradability	Low biodegradability inhibits process.	
Temperature outside 15 - 70 C range	Larger, more diverse microbial population present in this range.	Temperature monitoring
Nutrient deficiency	Lack of adequate nutrients for biological activity (although nutrient supplements may be added).	C/N/P Ratio
Oxygen deficiency	Lack of oxygen is rate limiting.	Oxygen monitoring
Moisture content	A moisture content of greater than 79% affects bacterial activity and availability of oxygen. A moisture content below 40% severely inhibits bacterial activity.	
pH outside 4.5 - 8.5 range	Inhibition of biological activity	Sludge pH testing

Adapted from the Environmental Protection Agency (EPA, 1988)

TABLE 4 continued.

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Microbial population	If indigenous microorganisms not present, cultured strains can be added.	Culture test
Presence of elevated levels of: Heavy Metals Highly chlorinated organics Inorganic salts	Can be highly toxic to microorganisms	Analysis for priority pollutant

Adapted from the Environmental Protection Agency (EPA, 1988)

favorable environmental conditions which allows the maximum level of degradation of contaminants (EPA, 1988). The initial step in the process is to create a slurry of the sludges being treated. The slurry is produced by adding available water, which may be contaminated. Stones and other rubble are removed from the slurry during this process. A typical slurry contains about 50% solids by weight; a slurried sludge may contain less. The actual solid content is based on laboratory results based on the concentration of contaminants, rate of biodegradation, and physical nature of the waste. The slurry is mechanically agitated in a reactor vessel to keep the solids suspended in order to maintain favorable environmental conditions. Inorganic and organic nutrients, oxygen and acid or alkali for pH control may need to be added to achieve

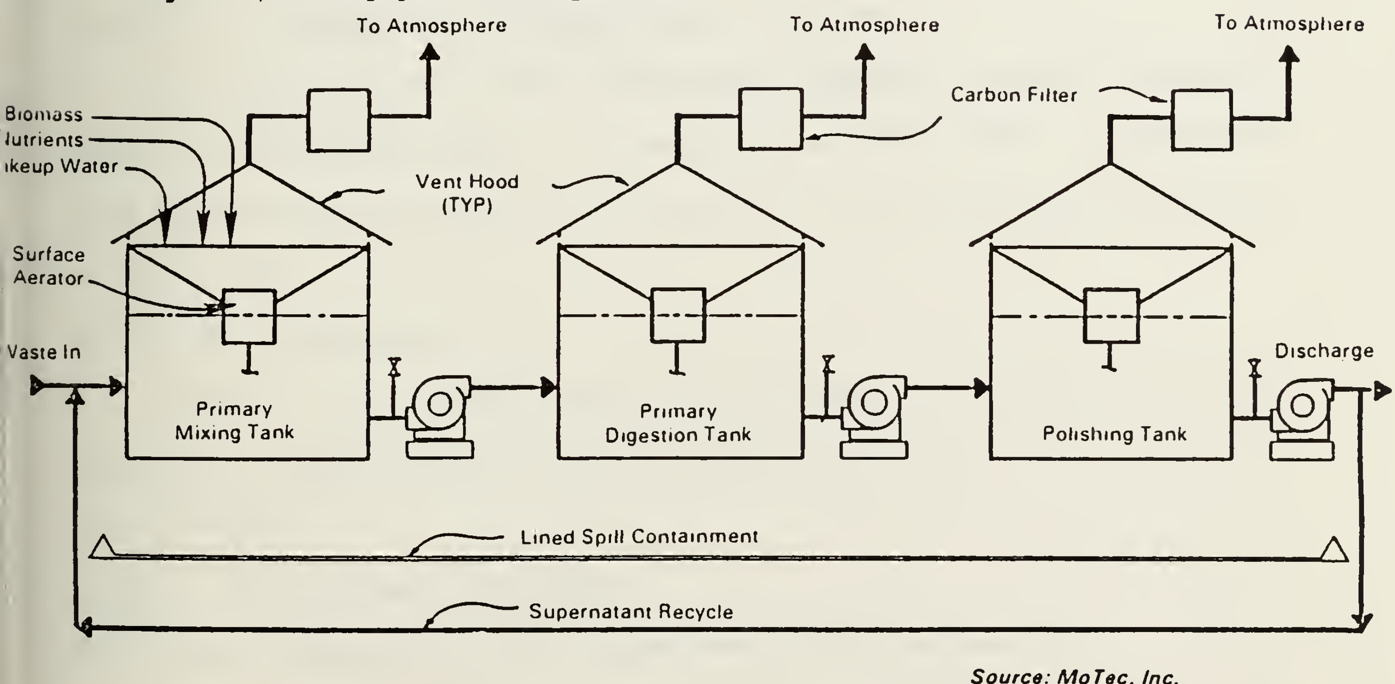
the best results. Initial seeding of the bioreactor with microorganisms may be required, or additional organisms may need to be added to correct biomass concentration. The treatment time may be one month or more depending on the type of contaminants, their concentrations, and the temperature in the tanks. Several firms market slurry-phase biological treatment systems, Figure 6 is a system marketed by MoTec, Incorporated.

IV-A-1-b. Advantages/disadvantages

Advantages:

1. Provides complete detruction of contaminants.
2. Remediation systems can be designed to pretreat wastes contaminated with heavy metals, semi-volatile, and volatile compounds.

Figure 6, Slurry-phase biodegradation



Adapted from the Environmental Protection Agency (EPA, 1988)

3. Soil washing and extraction of metals using weak acids and chelating agents can be combined with biological treatment by combining two separate slurry-phase reactors (EPA, 1988)

4. Availability of technology from a number of different firms.

Disadvantages:

1. Performance not verified on site.

2. Regulatory bodies have not generally accepted the technology as a preferred treatment process.

3. Heavy metals and chlorides may inhibit optimal bioreactor functioning due to their toxicity.

4. Residual water used in treatment may require further treatment prior to disposal.

IV-A-1-c. Demonstration/Field Tests results

The MoTec unit has been reportedly tested on liquids, sludges, and soils with high organic concentrations (EPA, 1988). A proposed SITE demonstration project for this unit, is scheduled to be tested in April 1990.

IV-A-1-d. Cost data

Cost data provided by Mr. Ron Lewis, EPA Project Manager (personal communication, April 17, 1990) estimated $130 - $170 per ton of waste.

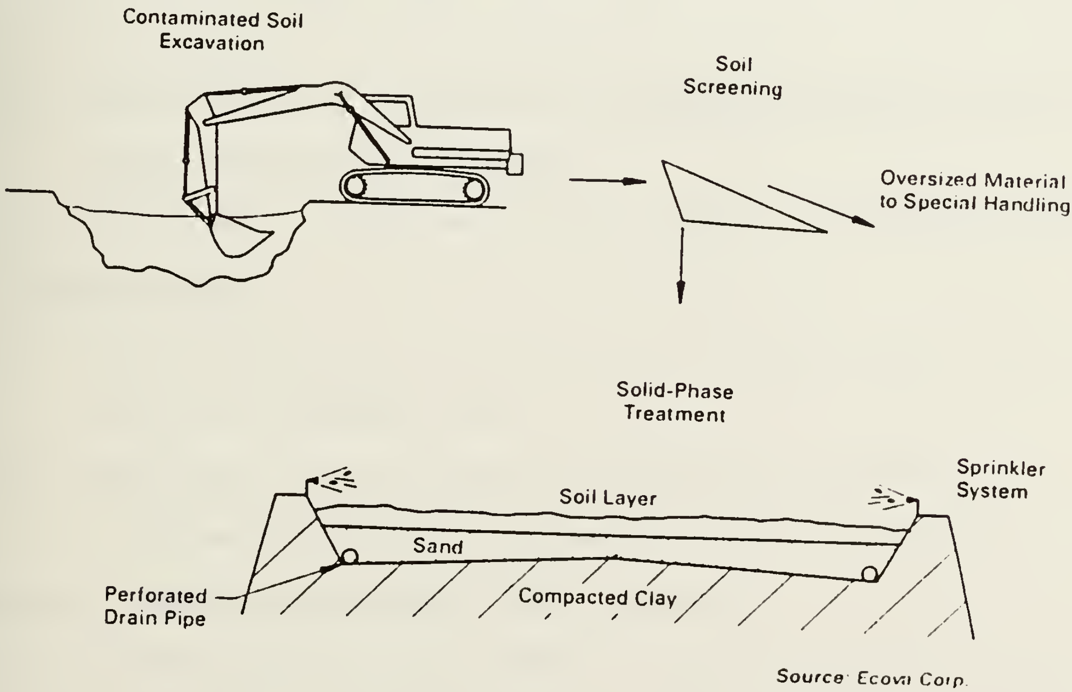
IV-A-2. Solid-Phase Treatment

IV-A-2-a. Description and operation of the technology

Solid-phase soil bioremediation is a process that treats soils

in an above ground system using conventional soil management practices which enhances the microbial degradation of contaminants (EPA, 1988). The treatment bed is equipped with a synthetic liner, covered by a sand bed which prevents contamination of the surrounding soil and groundwater, see figure 7. A perforated drainage pipe serves to collect contaminated soil leachate from the treatment bed. The leachate can then be transported to an on-site bioreactor which treats the leachate, which can later be used as source of microbial inocula and a distribution medium for nutrients needed to enhance biodegradation. An overhead spray irrigation system provides for moisture control and application of nutrients via the leachate.

Figure 7. Solid phase biodegradation



Adapted from the Environmental Protection Agency (EPA, 1988)

If volatile contaminants are to be contained, the entire bed is enclosed in a modified plastic film greenhouse. The greenhouse contains an air management system which collect Volatile Organic Compounds (VOC's) which may be released from the soil during the treatment. Biodegradable VOC's can be treated in a vapor phase bioreactor, and non-biodegradable VOC's may be removed from the effluent gas stream by adsorption on activated carbon or incineration.

IV-A-2-b. Advantages/Disadvantages

Advantages:

1. Full system, with vapor/leachate bioreactors offers permanent disposal option for contaminants.

2. Lower costs are reported for ultimate disposal compared to other conventional methods.
3. Technology is available from a number of different firms.

Disadvantages:

1. The technology has received limited testing in order to verify its capabilities.
2. Regulatory agencies have not generally accepted bioremediation as a preferred treatment process.

IV-A-2-c. Demonstration/Field Tests results

The technology has been used by various manufacturers on different wastes. A system manufactured by the MoTec Inc. reportedly treated oil field and refinery sludges (EPA, 1988). Another company, Ecova Inc., used their solid-phase system at a

Seattle, Wa. site contaminated by diesel fuel. The treatment process reduced the hydrocarbon level acceptable for treatment on-site and disposal at a landfill (Rubin et al., 1989).

IV-A-2-d. Cost info

Cost information on the solid-phase biodegradation system was limited to the Ecova Corporation's treatment of the site contaminated in Seattle, Wa.. The treatment reportedly reduced the cost of ultimate disposal from $200 to $50 per ton (Rubin et al., 1989).

IV-B. Physical and Chemical Treatment Technologies

The physical and chemical treatment technologies were combined due to their close association and frequent use together in the waste treatment process. Physical treatment processes separate the waste streams by either applying physical force, or changing the physical form of the waste. Commonly used physical processes are centrifugation, clarification, filtration, mechanical pressing, and sedimentation. Separation and drying accomplished in the physical treatment process reduces the volume of material for ultimate disposal. Combining chemical treatment processes with the physical processes enables one to further dry residual materials, make them less toxic, or to in some cases remove more harmful contaminants. This ideally will reduce ultimate disposal costs, as you are able to dispose of the less toxic wastes by cheaper disposal methods, such as landfilling. The general treatment technology for oily waste sludges is chemical extraction. Characteristics which

should be considered prior to using chemical extraction processes are provided in Table 5. Chemical extraction processes are used to separate contaminated sludges and soils into their respective phase fractions: organics, water, and particulate solids. A number of processes use this basic technology. The following technologies represent variations of chemical extraction processes by different companies being evaluated in the SITE program:

- Solvent Extraction
- Carver-Greenfield Process for Extraction of Oily Wastes
- Solvent Extraction (BEST)

Two other technologies categorized in the physical/chemical treatments were also reviewed. One of the technologies (in the SITE program) involved the decontamination by microfiltration. The final technology reviewed was one found in the literature and is not currently being evaluated by EPA. The process is a steam gasification process. Both processes may offer promise as future technologies, based on further substantiation of performance.

IV-B-1. Solvent Extraction

IV-B-1-a. Description and Operation of the Technology

This solvent extraction technology developed by the CF Systems Corporation (Figure 8) uses liquefied gas solvent to extract organics (such as hydrocarbons), oil, and grease from wastewater or contaminated sludges and soils. Carbon dioxide is used in processes involving aqueous solutions, while propane or butane is used for extractions involving soils, sediments, or sludges.

TABLE 5. TECHNOLOGY SUMMARY
WASTE TYPE: Soils and Sludges
TECHNOLOGY: Chemical Extraction

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Presence of elevated levels of volatiles	Volatiles may combine with process solvent, requiring an additional separation step.	Volatile organic analysis *
Particle size greater than 1/4 inch	Equipment used in process not capable of handling large particle size. Waste must be pumpable.	Particle size * distribution
pH < 10	TEA (used in BEST process) is weak base will exist in solvent form only at approximately pH $\geq$ 10. Wastes with lower pH must be pretreated to raise pH.	pH measurement *
Presence of high amounts of emulsifiers	Adversely impact oil/water phase separation. A greater quantity of solvent is required for appropriate treatment.	Glassware * process simulation to measure phase separation characteristics
Metals (e.g., aluminum) or other compounds that undergo strong reactions under highly alkaline conditions	Strong reactions may occur during treatment process because of caustic addition. The adverse reaction may be avoided by using TEA for pH adjustment.	Analysis for aluminum *

Adapted from the Environmental Protection Agency (EPA, 1988)
* Information supplied by Resources Conservation Co.

TABLE 5 continued,

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Types of waste	Materials contaminated with heavy metals not suitable. Wastes that are reactive with carbon dioxide and propare must be pretreated. Wastes containing > 200 ppm organics and oil concentration up to 40 percent are acceptable.	Metal analysis**

Adapted from the Environmental Protection Agency (EPA, 1988)
** Information supplied by CF Systems Corp.

The process begins as the sludges, slurrys or wastewaters are fed into the extractor. The solvent, gas condensed by compression, is also fed into the extractor, making nonreactive contact with the waste. The solvent typically separates more than 99 percent of the organics from feedwaste (EPA, 1989). Following phase separation of the solvent and organics, treated water is removed from the extractor. The remaining mixture of solvent and organics pass into the separator via a valve where the pressure is partially reduced. In the separator the solvent is vaporized and recyled as fresh solvent. The organics are drawn off from the separator, and either reused or disposed.

IV-B-1-b. Advantages/Disadvantages

<u>Advantages:</u>

1. Separates various phases and contaminants.

2. Simplicity of operation.

3. Smaller units are available and proven.

4. Available from a number of companies.

5. Treatment can reduce ultimate disposal costs, if materials are rendered less toxic.

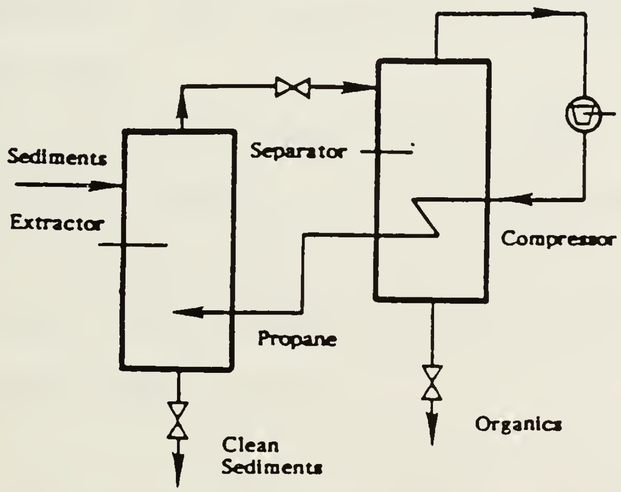
Disadvantages:

1. Waste must be pumpable

2. Additional treatment may be required prior to ultimate disposal.

3. Heavy metal analysis is required. Materials with heavy metals are not suitable for treatment.

Figure 8. Solvent extraction unit process diagram.



Adapted from the Environmental Protection Agency (EPA, 1989)

IV-B-1-c. Demonstration/Field Tests results

This unit has been demonstrated on PCB contaminated sediments from dredging operations conducted by the U.S. Army Corps of Engineers. The following tests results include the number of passes made during each test and the concentration of PCB's before and after each test (EPA, 1989):

	Passes	PCB concentration Before	After
Test 2	9	360 ppm	8 ppm
Test 3	3	288 ppm	82 ppm
Test 4	6	2575 ppm	200 ppm

Various units are in operation throughout the U. S. Of particular note is a unit in operation at Star Enterprise, Port Arthur, Texas, treating API separator sludge to meet Best Demonstrated and Available Technology (BDAT) standards for organics.

IV-B-1-d. Cost data

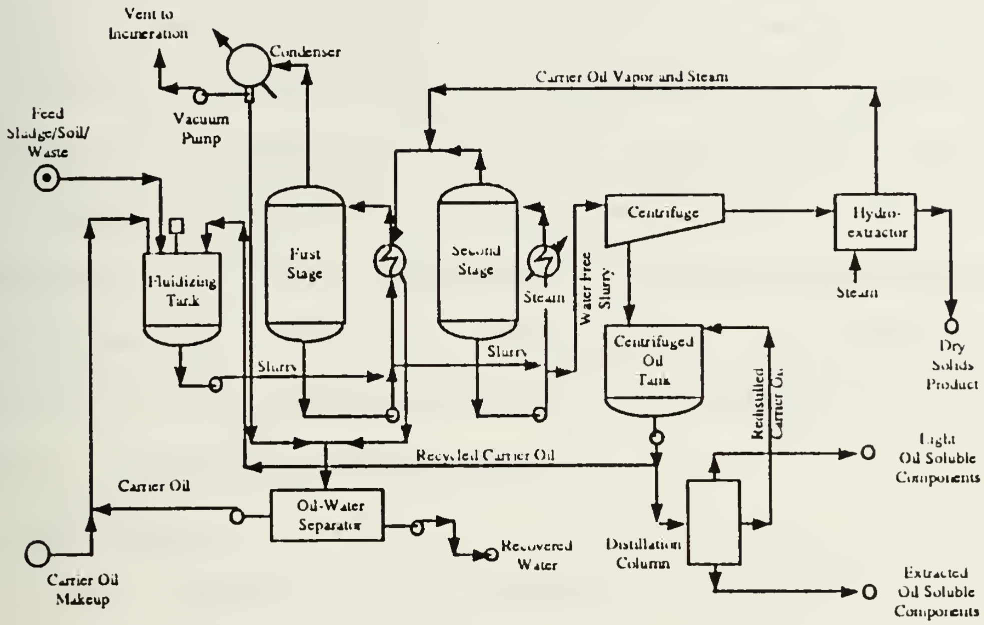
Projected cost for PCB cleanups are estimated to be approximately $150 to $450 per ton, including material handling and pre- and post- treatment costs. Costs are highly sensitive to the utilization factor and job size, which may result in lower costs for large cleanups (EPA, 1989).

IV-B-2. Carver-Greenfield Process for Extraction of Oily Wastes

IV-B-2-a. Description and Operation of the Technology

The Carver-Greenfield Process manufactured by the Dehydro-Tech Corporation (Figure 9) is also designed to separate materials into their constituent solid, oil, and water phases.

Figure 9. Simplified Carver Greenfield process flow diagram.



Adapted from the Environmental Protection Agency (EPA, 1989)

It is intended especially for oil-soluable hazardous organics that are concentrated in the oil phase. The technology uses a food-grade "carrier oil" to extract the oil-soluable contaminants. The carrier oil, waste sludge or soil enter into the Fluidizing Tank where stones and any metal present are separated from the slurry. Pretreatment is necessary to achieve particle sizes of less than 1/4-inch.

The mixture of carrier oil and waste sludge (or soil) is placed in the evaporation system to remove any water. A carrier oil with a boiling point of 400°F is typically used. The oil serves to fluidize the mix and maintain a low slurry viscosity to ensure efficient heat transfer, and allowing essentially 100 percent of the water to evaporate. Mixing with the carrier oil

allows the oil-soluable contaminants to be extracted from the waste. In this step volatile compounds are stripped out of the waste and condensed with the carrier oil or water. In the next step the water is evaporated from the mixture, and the dried slurry is sent to the centrifuging section to remove most of the carrier oil. Residual carrier oil is removed by a process called "hydroextraction". The carrier oil is recovered by evaporation and steam stripping. Hazardous constituents are removed from the carrier oil by distillation, and can be disposed of or reclaimed.

IV-B-2-b. Advantages/Disadvantages

Advantages:

1. The process has been commercially applied to a number of waste streams.
2. The process allows for recovering of oils via distillation.
3. Allows recovery of 75% to 80% of energy contained in solids if materials are used for incineration.

Disadvantages:

1. Additional treatment may be required prior to ultimate disposal.
2. Residual material requires ultimate disposal.
3. Presence of high amounts of emulsifiers will adversely impact oil/water phase separation.

IV-B-2-c. Demonstration/Field Tests results

The Carver-Greenfield Process® has been commercially applied in over 65 installations throughout the world. The process has

been used on food processing wastewaters with the resulting residual product being a dry and virtually sterile material. EPA has successfully tested the process in a pilot plant on refinery "slop oil", consisting of approximately 72% water, as well as mixed refinery waste consisting of DAF, API separator bottoms, tank bottoms, and biological sludge (EPA, 1989).

IV-B-2-d. Cost data

Not available.

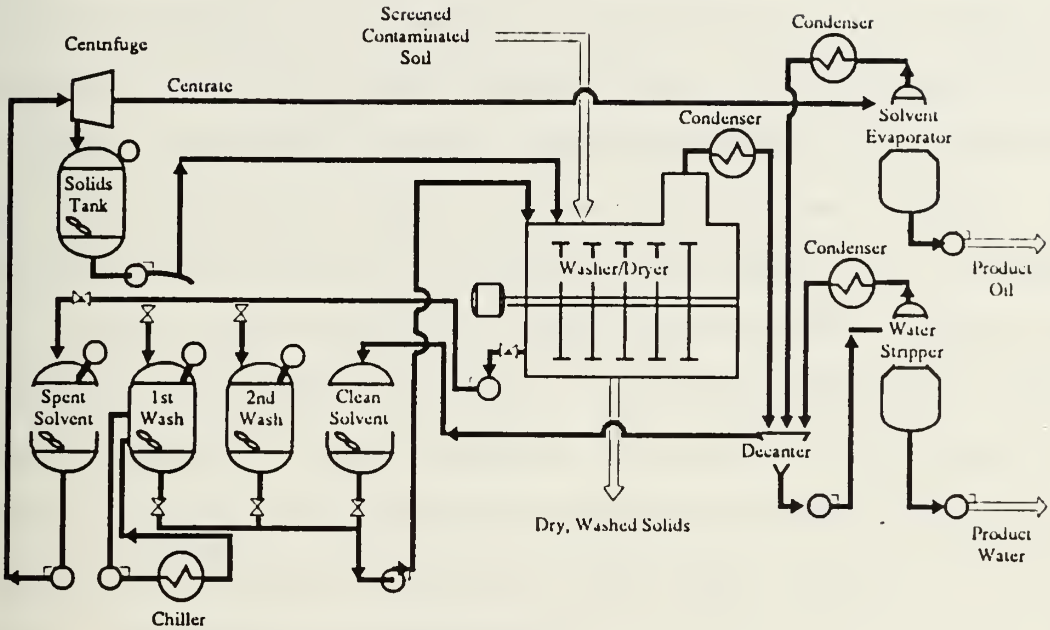
IV-B-3. Solvent Extraction (BEST process)

IV-B-3-a. Description and Operation of the Technology

The Basic Extraction Sludge Treatment (BEST) developed by the Resources Conservation Company, is a mobile solvent extraction system (Figure 10). It has been used mainly to treat oily sludges containing hydrocarbons and other high molecular weight organics (EPA, 1988). Like other chemical extraction processes, the BEST process separates the sludges into three fractions: oil, water, and solids. In doing so the process partitions the contaminants into specific phases. By doing this the overall volume and toxicity of the original waste solids are reduced and the concentrated waste streams can be efficiently treated for disposal.

The process uses one or more secondary or tertiary amines (usually triethlylamine (TEA)) to separate the hydrocarbons from sludges. The technology is based on the fact that TEA is completely soluable in water at 20°C (EPA, 1989). Due to TEA's

Figure 10. BEST solvent extraction process



Adapted from the Environmental Protection Agency (EPA, 1989)

flammability in the presence of oxygen the treatment is sealed and operated under a nitrogen blanket. Pretreatment of the sludges, or soils includes: screening the material to remove pebbles and debris to ensure smooth flow, and raising the pH of the material undergoing treatment to greater than 10. This creates an atmosphere where the TEA will be conserved for recyling.

The pH adjustment is usually accomplished with the addition of sodium hydroxide. The process begins by mixing and agitating the cold solvent and waste in a washer/dryer. At the low temperature the solvent is completely miscible with the hydrocarbons and water. As the solvent breaks the oil-water-solid bonds in the waste, the

solids are released and allowed to settle. The solvent mixture is decanted and the fine particles are centrifuged for removal. The resulting dry solids are cleansed of hydrocarbons, but contain any heavy metals contained in the original waste. The liquids from the washer/dryer which now contain the hydrocarbons and water are heated to separate the water from the organics and solvent. The organics-solvent fraction is decanted and sent to a stripping column, where the solvent is recycled and the organics are discharged for disposal. The water fraction is passed to a second stripping column, where residual solvent is recovered for recycling. The water is normally capable of being discharged to the municipal wastewater treatment plant (EPA, 1989).

IV-B-3-b. Advantages/Disadvantages

Advantages:

1. The unit is mobile; portability enhances on-site treatment.
2. By removing the organic contaminants, the process reduces the overall toxicity of solids and water streams.
3. Residual solids from the process are dry and in many cases may not require further treatment before disposal.
4. The process concentrates the contaminants into a smaller volume, which allows for efficient final treatment and disposal.
5. Process has been proven effective on many of the RCRA listed hazardous wastes found in Navy fuel terminals and petroleum operations (DAF float, slop oil emulsions, API

separator sludge, leaded tank bottoms)

Disadvantages:

1. Sludges must be pretreated to achieve a pH of > 10.
2. Process is particle size restrictive (particles must be less than 1/4 inch)
3. Presence of high amounts of emulsifiers will adversely impact oil/water phase separation.
4. Residuals require further treatment in many cases; not an ultimate disposal process.

IV-B-3-c. Demonstration/Field Tests results

The first full-scale BEST unit was used at the General Refining Superfund site in Garden City, Georgia (EPA, 1989). The BEST process' demonstration under the SITE Program is pending selection of an appropriate site.

IV-B-3-d. Cost data

Not available.

IV-B-4. Leaching and Microfiltration

IV-B-4-a. Description and Operation of the Technology

In this process, soils and sludges are decontaminated by leaching and microfiltration. The process, capable of handling widely varying incoming solids concentrations, is used to decontaminate sludges containing heavy metals such as barium, cadmium, chromium, lead, molybdenum, mercury, nickel, selenium, silver, and zinc. The technology developed by Epoc Water, Inc. uses a process consisting of three main steps (Figure 11):

1. Chemical leaching to solubilize the metals in the waste;
2. Separation of the solids by using a specially designed automatic tubular filter press, and washing the waste in-situ; and
3. Precipitation of metals using a proprietary microfiltration method, and dewatering.

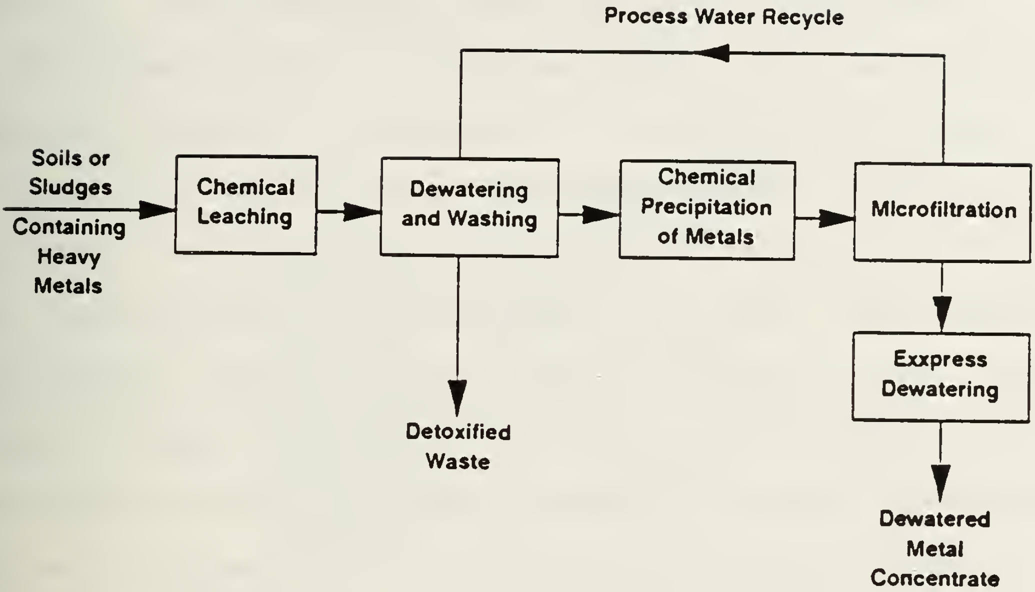
The leaching process can be accomplished in most cases using low cost mineral acids or alkalis. In special circumstances, chelating agents can also be used to remove a particular metal. The leached slurry containing the solubilized metals is separated by the automatic tubular filter press. Chemical treatment of the resulting filtrate precipitates the heavy metals in hydroxide form. The residual organic contamination can be removed with activated carbon. Heavy metals in the precipitate are concentrated by microfiltration, using an innovative and flexible woven textile material capable of separating particles as small as 0.1 microns (EPA, 1989).

IV-B-4-b. Advantages/Disadvantages

Advantages:

1. The technology is transportable and skid mounted.
2. The process is relatively insensitive to metal content. It is able to process solids with metal concentrations up to 10,000 mg/kg.
3. The unit can treat approximately 30 pounds of solids per hour.

Figure 11. Leaching and Microfiltration process



Adapted from the Environmental Protection Agency (EPA, 1989)

<u>Disadvantages</u>:

1. The process is specifically suited to treating heavy metals. Must be combined with other treatment methods for organic contaminant treatment.
2. This is not an ultimate disposal process. Residuals must be disposed of.

IV-B-4-c. Demonstration/Field Tests results

The technology was accepted into the SITE Demonstration program in October 1989. The project has not been demonstrated in the program due to the recent arrival.

IV-B-4-d. Cost data

Not available.

IV-B-5. Steam Gasification Technology

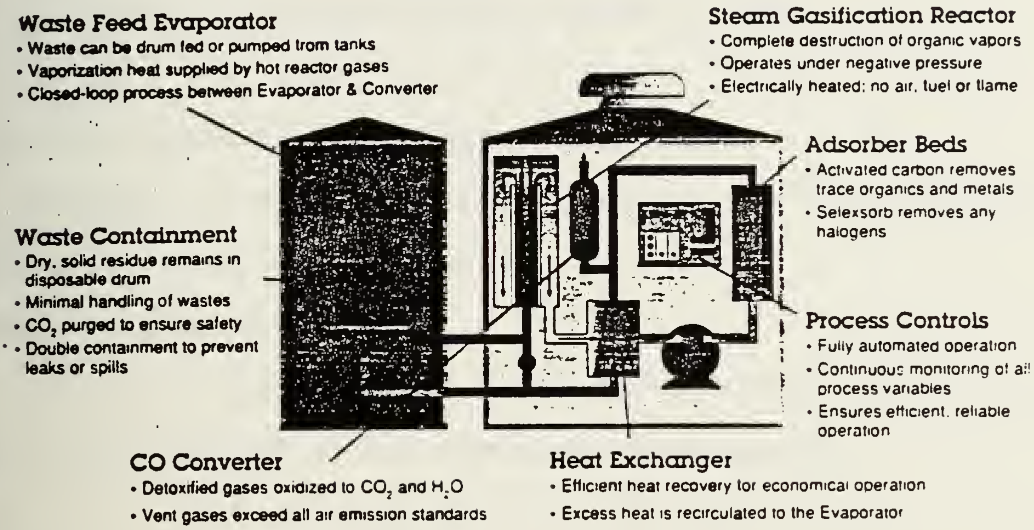
IV-B-5-a. Description and Operation of the Technology

The Thermolytica™ detoxifier (TLD), a steam gasification technology offers an alternative to incineration for the small generator (Galloway, 1989). The unit operates on a new chemical process not using air in any open flame combustion. Hazardous waste destruction is accomplished by very high temperature (approaching 1,650°C) steam gasification chemistry. The key features of the technology are the use of atmospheric pressure, steam-hydrocarbon gasification chemistry using non-combustible mixtures, a unique chemical reactor design which provides the right turbulence, temperature, and residence time to achieve 99.99% destruction. The unit, see Figure 12, is composed of a steam gasification converter (SGC), and one or more waste feed evaporators (WFE). "The SGC is four feet by six feet by seven and one-half feet and uses standard industrial electrical power, and the WFE is four feet by five feet by six and one-half feet" (Galloway, 1989). The WFE receives wastes by pumping from tanks or by receiving drums directly into the unit, without having to remove the waste from the drum.

In the process the stream "Vapor" is pulled into the SGC under a slight vacuum. The vaporization of the hazardous waste occurs in the WFE. After the SGC removes the wastes, hot gas is generated and fed to the vaporizers to pick up more hazardous waste. Pressure balance is maintained by venting a small stream of clean gas. The system is fully automated, so the operator only has to

place the waste in the WFE and press the "on" button. The Thermolytica unit must be preapproved before operation as part of the DOHS/EPA permit (Galloway, 1989).

Figure 12. Steam gasification technology. (Thermolytica[TM])



Adapted from Environmental Progress (Galloway, 1989)

IV-B-5-b. Advantages/Disadvantages

Advantages:

1. The waste generator's liability is minimized by not using transporters and off-site disposal.
2. The unit is compact, and automated to allow easy operation by personnel.
3. Destruction levels reportedly exceed 99.99% .
4. Vent gases are mainly carbon dioxide and water for most

organics, so no downstream environmental controls are necessary.

5. Projected costs are competitive with other methods.

Disadvantages:

1. Technology has not been tested by EPA.

IV-B-5-c. **Demonstration/Field Tests results**

Evidence of the unit being demonstrated and evaluated by a regulatory agency was not found.

IV-B-5-d. **Cost data**

Cost provided in the literature (Galloway, 1989) estimated cost at between $48-275 per drum of liquid waste.

IV-B-6. **Wet-Air Oxidation**

Another technology that may offer some promise for future oily waste sludge disposal, is a Wet-Air Oxidation process (Wet-Air oxidation, is also considered a thermal process when performed at high temperatures and pressures). Wet-air oxidation is a semi-commercial process that has been used to treat a variety of weakly toxic chemical wastes and for the regeneration of activated carbon. This process may offer savings, when compared to incineration, on more dilute wet hazardous wastes that contain less than 30% organics. This waste characterization applies to the Navy oily waste sludges. Wastes that are dilute to moderately dilute, e.g., 1-30% oxidizable waste can be economically destroyed without initially dewatering the waste (Unterberg et al., 1988). The

process is accomplished by the destruction of waste compounds by dissolved oxygen in a moderate temperature (130-400°C) aqueous phase. The current disadvantage to the process is the long reaction time required due to the moderate temperatures. Unterberg et al. (1988) suggests that the process is a viable alternative to incineration but further research is required in the areas of "reaction mechanisms and pilot plant operation". The process is currently being developed in Dorset, England by the Winfrith Technology Centre for the treatment of radioactive waste ("Wet oxidation alternative", 1989). The wastes after treatment are encapsulated for final disposal. Hydrogen peroxide at 50% strength is used after the waste slurry is heated to a temperature between 80-90°C ("Wet oxidation alternative", 1989). The process treats waste in 200kg batches over a 4-6 hour period.

The wet-air oxidation process is seen as a viable technology for oily waste disposal in the future. Currently there is only one technology being evaluated in the SITE Program using wet air oxidation in the process. The technology developed by Zimpro/Passavant Inc. is being evaluated for its applicability in treating municipal and industrial wastewaters (EPA, 1989). The wet air oxidation process appears to offer an alternative to incineration of oily waste. Technologies should be evaluated as they are developed for applicability to Navy oily waste disposal.

IV-C. Solidification and Stabilization Technologies

Solidification and stabilization technologies, also called

chemical fixation, entrap hazardous waste material in chemical matrix which is impervious to water penetration and subsequent leaching. The goal of the solidification and stabilization technologies is to "solidfy" contaminants in a matrix in order to allow disposal in landfills. The technologies must stabilize constituents to prevent leaching of contaminants into the environment. Wastes must meet the Toxicity Characteristic Leaching Procedures (TCLP) standards established by EPA. The TCLP is designed to determine the mobility of both organic and inorganic contaminants present in liquid, solid, or multiphase wastes (CFR Title 40, Part 268, Appendix A, section 1.1).

In general, solidization and stabilization technologies are categorized by their principal additives, such as: cement based, pozzolanic, thermoplastic, organic polymer, surface encapsulation, self-cementing, and glassification (Potter et al., 1986). Data suggests that silicates used with lime, cement, or other setting agents are able to stabilize a wider range of materials than cement-based technologies (EPA, 1988). Stabilization and solidification has been shown to be effective in treating petroleum refining tank bottom sludges, but the treatment process is highly dependent on sludge characteristics. Table 4 lists some of these factors and how their impact can be assessed. There are currently six companies participating in the SITE Program using solidization and stabilization technologies applicable to oily waste sludge treatment. Three technologies will be discussed. Two of the technologies selected have been successfully tested on petroleum

TABLE 6. TECHNOLOGY SUMMARY
WASTE TYPE: Soils and Sludges
TECHNOLOGY: Stabilization/solidification

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Organic content should be no greater than 20-45% by weight when using cement-based technologies	Organics interfere with bonding of waste materials	Analysis for volatile solids, total organic carbon
Semivolatile organics greater than 10,000 ppm PAHs greater than 10,000 ppm	Organics interfere with bonding of waste materials.	Analysis for semivolatile organics, PAHs
Waste with less than 15% solids	Large volumes of cement or other reagents required, greatly increasing the volume and weight of the end product. Waste may require reconstitution with water to prepare waste/reagent mix.	Analysis for total solids and suspended solids
Oil and grease should be less than 10% when using cement-based technology	Weakens bonds between waste particles and cement by coating the particles.	Analysis for oil and grease

Adapted from the Environmental Protection Agency (EPA, 1988)

TABLE 6 continued,

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Fine particle size	Insoluable material passing through a No. 200 mesh sieve can delay setting and curing. Small particles can also coat larger particles, weakening bonds between particles and cement or other reagents. Particle size greater than 0.25 inches in diameter not suitable.	Soil particle size distribution
Halides	May retard setting, easily leached	Analysis for total halides
Soluble salts of manganese, tin, zinc, copper, and lead	Reduce physical strength of final product; cause large variations in setting time; reduce dimensional stability of the cured matrix, thereby increasing leachability potential.	Analysis for inorganic salts
Cyanides greater than 3,000 ppm	Cyanides interfere with bonding of waste materials.	Analysis for cyanides
Sodium arsenate, borates, phosphates, iodates, sulfide, and carbohydrates	Retard setting and curing and weaken strength of final product.	Bench-scale testing
Sulfates	Retard setting and cause swelling and spalling	Analysis for sulfate

Adapted from the Environmental Protection Agency (EPA, 1988)

TABLE 6 continued,

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
Volatile organics	Volatiles not effectively immobilized. Driven off by heat of reaction.	Analysis for volatile organics, bench-scales testing
Presence of leachable metals	Effectiveness of stabilization methods may vary.	Analysis for priority pollutants, bench-scale testing
Phenol concentration greater than 5%	Results in marked decreases in compressive strength.	Analysis for phenols
Presence of coal or lignite	Coals and lignite can cause problems with setting, curing, and strength of the end product.	Core sampling with specific analysis for coal

Adapted from the Environmental Protection Agency (EPA, 1988)

sludges. The third technology, a glassification process, was selected because it combines the destructive capabilities of incineration while encapsulating the hazardous contaminants. The technologies developed represent the following:

- In Situ Solidification/Stabilization process
- Mobile Solidification/Stabilization process
- Glassification process

IV-C-1. In Situ Solidification/Stabilization Technology (International Waste Technologies/Geo-Con, Inc.)

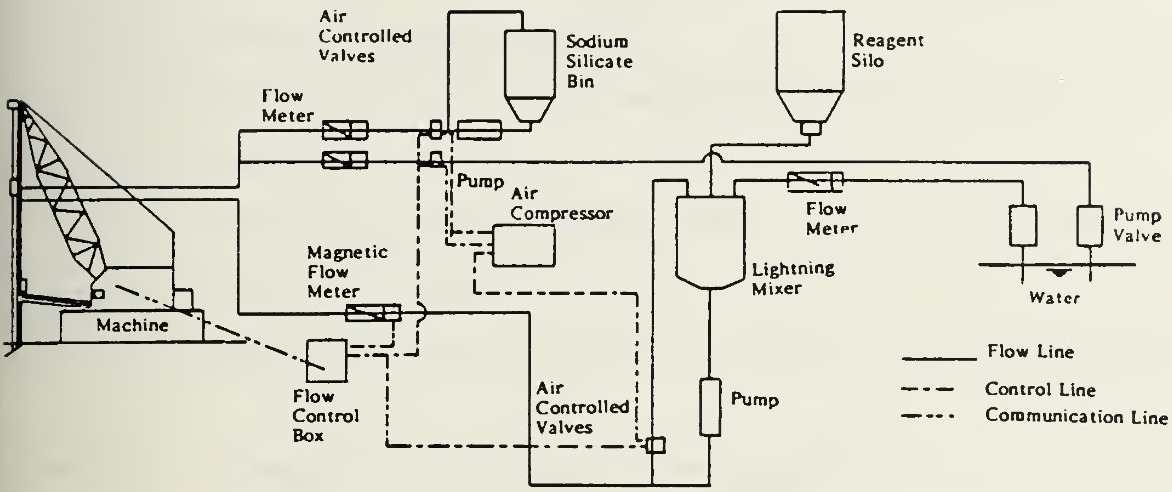
IV-C-1-a. Description and Operation of the Technology

This in situ solidification and stabilization technology immobilizes organic and inorganic compounds in wet or dry soils, using additives to produce a cement-like mass (EPA, 1989). The obvious advantage of the technology is the use of the solidification/stabilization process on location. The basic components of the technology (Figure 13) are:

1. A deep soil mixing system (DSM) which delivers and mixes the chemicals with the soils in place.
2. A batch mixing plant which supplies the proprietary mixing chemicals.

The additives generate a complex, crystalline, connective network of inorganic polymers, which are mainly covalent bonds. The process involves a two-phase reaction where contaminants are initially complexed in a fast reaction, and then in a slow-acting reaction, the building of macromolecules continues over a long period of time. Amounts of additives must be determined, as it varies depending on waste type (EPA, 1989). The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing that are attached to a vertical drive auger, which rotates at approximately 15 rpm. Two conduits in the auger are used to inject the additives and water. Additive injection occurs on the downstroke, and further mixing takes place on withdrawal of the auger. The treated soil columns are 36 inches in diameter, and are positioned in an

Figure 13. In Situ Solidification/Stabilization Process (International Waste Technologies/Geo-Con, Inc.)



Adapted from the Environmental Protection Agency (EPA, 1989)

overlapping pattern of alternating primary and secondary soil columns (EPA, 1989).

IV-C-1-b. Advantages/Disadvantages

<u>Advantages:</u>

1. System can be used in almost any soil type.
2. The process is economic.
3. Microstructural analyses of the treated soils indicated a potential for long term durability. High unconfirmed compressive strengths and low permeabilities were recorded.
4. Can be used on both organics and inorganics.
5. Smaller increase in volume of treated soil less than other solidification/stabilization technologies.

Disadvantages:

1. Limited field data exist on design and operation.
2. Additives can be costly.
3. Treatment can produce vapors needing collection and treatment.
4. Long term durability not known, may lead to future liability issues.
5. Labor intensive, requires constant operating personnel.

IV-C-1-c. Demonstration/Field Tests results

A SITE demonstration took place on a PCB-contaminated site in Hialeah, Florida in April 1988. Two 10 x 20-foot test sectors of the site were treated. One to a depth of 18 feet, and the other to a depth of 14 feet. Long term monitoring tests 10 months after the demonstration produced the following results:

- Based on TCLP leachate analysis, the process appears to immobilize PCBs.
- The bulk density of the soil increased 21% after treatment, increasing the volume of treated soil by 8.5% and causing small ground rises of one inch per treated foot.
- The unconfined compressive strength (UCS) was satisfactory, with values of 300 to 500 psi.
- The permeability of treated soil was satisfactory, decreasing four orders of magnitude compared to the untreated soil.
- The wet/dry weathering test on treated soil was

satisfactory. The freeze/dry weathering test of treated soil was unsatisfactory.

- The microstructural analysis showed that the treated material was dense, non-porous, and homogeneously mixed.
- The Geo-Con DSM equipment operated reliably.

IV-C-1-d. Cost data

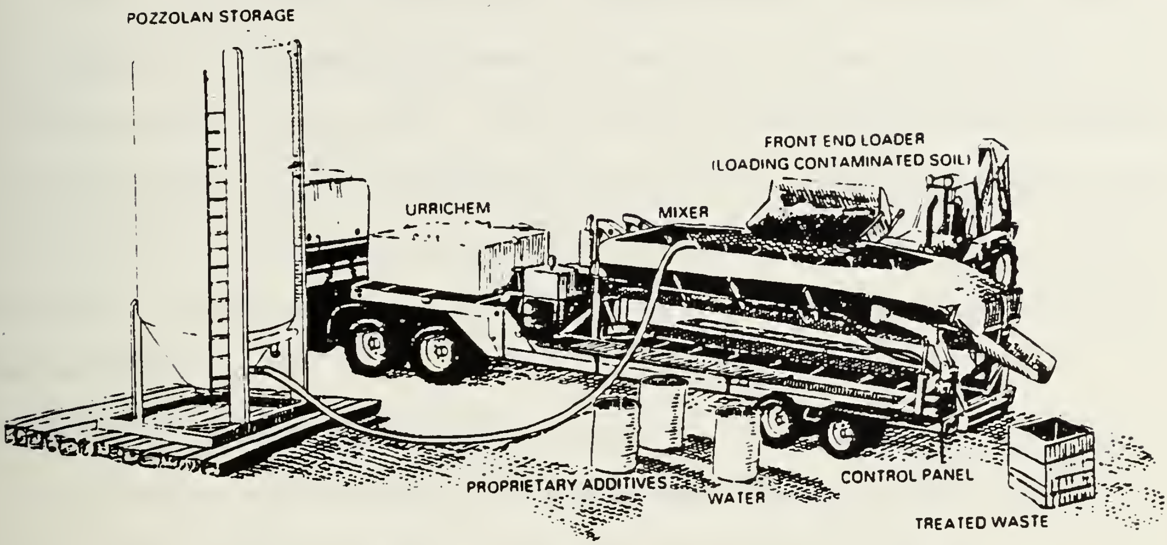
The process is economic: $194 per ton for the 1-auger machine used in the demonstration; and $110 per ton for a commercial 4-auger operation (EPA, 1989).

IV-C-2. Mobile Solidification/Stabilization Technology (Soliditech, Inc.)

IV-C-2-a. Description and Operation of the Technology

Soliditech offers a truck mounted solidification/stabilization technology which enables treatment on location (Figure 14). The process immobilizes contaminants in soils and sludges by binding them in a concrete-like matrix. Contaminated materials must be prescreened to remove oversized material. The material is placed in the trailer mounted batch mixer where it is mixed with (1) water, (2) Urrichem, a proprietary chemical reagent (3) other proprietary additives (4) pozzolanic material (fly ash), kiln dust, or cement (EPA, 1989). Once thoroughly mixed the treated waste is discharged from the mixer. The end result of the process is a stabilized mass which is reportedly capable of landfill disposal.

Figure 14. Mobile Solidification/Stabilization Process (Soliditech, Inc.)



Adapted from the Environmental Protection Agency (EPA, 1989)

IV-C-2-b. **Advantages/Disadvantages**

<u>Advantages:</u>

1. Successful treatment enables disposal by landfills, a cheaper disposal medium.
2. Process is mobile, can treat materials on location.
3. Technology is currently available.

<u>Disadvantages:</u>

1. Residual mass requires ultimate disposal.
2. Long term stability of the process requires further evaluation.
3. Process produces increased volume; greater disposal costs.
4. Liability issue could be a factor in the future if encapsulation fails leaching contaminants.

IV-C-2-c. Demonstration/Field Tests results

The Soliditech process was demonstrated in December 1988 at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. This location contained both chemical processing and oil reclamation facilities. Wastes treated were contaminated with petroleum hydrocarbons, PCBs, other organic chemicals, and heavy metals (EPA, 1989). Key findings from the demonstration were:

- Heavy metals were immobilized.
- Process solidifies both solid and liquid wastes with high organic content as well as oil and grease.
- Volatile organic compounds in original waste were not detected in treated waste.
- PCBs were not detected in any extracts or leachates of the treated waste.
- Physical test results showed: (1) unconfined compressive strengths ranging from 390 to 860 psi (2) very little weight loss after 12 cycles of wet/dry and freeze/thaw durability tests (3) low permeability of treated waste (4) increased density after treatment.
- Solidified waste increased in volume by an average of 22 percent.
- Semivolatile organic compounds (phenols) were detected in the treated waste and TCLP extracts. These were not discovered in the untreated waste so presence of compounds is believed to be due to chemical reactions with

mixtures/additives in the process.

IV-C-2-d. Cost data

Cost not available.

IV-C-3. Glassification Technology (Pacific Northwest Laboratories, Division of Battelle Northwest)

A glassification process developed at Pacific Northwest Laboratory may be the solidification/stabilization process of the future. It appears to effectively combine the processes of both incineration and solidification/stabilization. The process is based upon vitrification technology developed over the past 20 years for the treatment of radioactive liquid waste (Sather, 1988). It is suitable for direct treatment of combustible waste due to a recently developed feeding technique which allows the waste to be introduced below the surface of a molten glass pool.

IV-C-3-a. Description and Operation of the Technology

A schematic of the glassification process is provided in Figure 15. In the process, hazardous slurries, solutions, contaminated soils or miscellaneous solids are fed into a melter, where temperatures greater than 1150° C destroy the organic materials and convert hazardous inorganic materials to ash. The melter is basically a high-temperature glass melting furnace. Residual ash is dissolved in a pool of molten glass inside the melter (Sather, 1988). The molten material is then emptied into disposal drums, where it cools and solidifies.

The process includes an effluent treatment system that removes and neutralizes acidic gases generated by the combustion of

nitrate-bearing materials and certain plastics. Glass is an excellent medium for encapsulating hazardous waste. Molten glass can dissolve most inorganic materials, and solid glass is highly resistant to groundwater leaching. Because glass waste forms are predictably stable, hazardous wastes treated should pass the EPA toxic leaching test. If so, these by-products could be classified as nonhazardous material suitable for disposal on site or at landfills (Sather, 1988).

Battelle-Pacific Northwest Laboratory (1990) has also designed a mobile, integrated treatment system with an estimated production capability of 5 tons/day.

IV-C-3-b. Advantages/Disadvantages

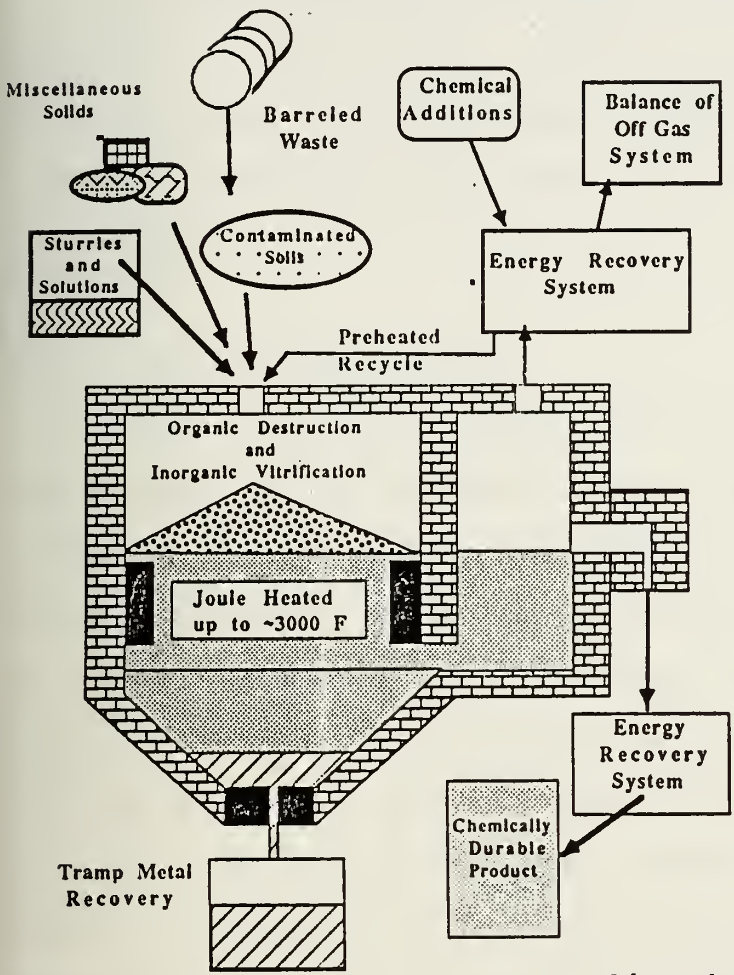
Advantages:

1. Process accommodates broad range of wastes.
2. Produces durable residuals, capable of landfill or on-site disposal.
3. Reduces volume of residuals, by in some reported cases, as much as 90% (Sather,1988).
4. Process, reportedly competitive with other solidification and stabilization processes due to savings from volume reduction and transport and disposal costs.

Disadvantages:

1. Process is not commercialized, and not currently available for treatment.
2. Evaluation to verify results has not been performed by EPA.

Figure 15. Glassification process
(Battelle-Pacific Northwest Laboratory)



Adapted from the Battelle-Pacific Northwest Laboratories(1990)

IV-C-3-c. Demonstration/Field Tests results

The technology has not been tested by EPA in the SITE program. Information from Pacific Northwest Laboratories indicated that destruction efficiencies greater than 99% have been achieved on organochlorine, organophosphorous, and organosulfur compounds. Testing on selected waste containing barium, chromium, lead, and arsenic indicated leaching and EP Toxicity leachate concentration limits, below that defining a material as hazardous.

IV-C-3-d. Cost data

Processing estimates provided by Sather (1988) range from $700 to $3500 per cubic meter. Lower transport and disposal costs resulting from greater volume reduction reportedly make the treatment competitive with other solidification/stabilization technologies.

IV-D. Thermal Technologies

Thermal treatment technologies depend on the use of high temperatures as the principal means of destroying or detoxifying hazardous wastes. Thermal treatment while not considered an ultimate hazardous waste disposal process, destroys the hazardous or toxic components in the waste matrix. The destructive capability of thermal treatments has taken on a new perspective with new environmental regulations. Companies and industries are now held responsible for past disposal methods, and assigned cleanup responsibility for disposal sites. Thermal treatment essentially reduces or eliminates future liabilities and risks associated with hazardous waste disposal. The "landban" regulations, emphasis on hazardous waste site cleanup, and addition of new wastes to the hazardous category has enabled the thermal treatments to return to competition with other disposal methods. The market for incineration, alone, doubled between 1985-1988, and is expected to rise about 25% per year through 1992 (Goldbaum et al., 1989). EPA's research data and industry's operating experience indicate incineration, when compared to the other

alternative technologies, has been found to have the highest overall degree of destruction and control for the broadest range of contaminants (Lee & Huffman, 1989). All of these factors have contributed to the interest in innovative technologies in this particular area. Thermal processing methods that have been developed and proven, or that are in the development stage for hazardous waste sludge treatment are:

- Fluidized bed incineration
- Rotary kiln incineration
- Infrared thermal treatment
- Wet air oxidation treatment
- Pyrolytic incineration

Thermal technologies to be discussed in relation to oily waste sludge treatment will be:

- Fluidized bed incineration
- Rotary kiln incineration
- Infrared thermal treatment

General characteristics which should be evaluated prior to selecting thermal treatments are provided in Table 7.

IV-D-1. Fluidized bed incineration

IV-D-1-a. Description and Operation of the Technology

A fluidized bed incinerator is a refractory-lined vessel containing inert granular material. Combustion air is blown through the bed to make a "fluid" of the granular material. Solids, sludges, or liquids can be injected directly into the bed or at its surface. The heating value of the wastes plus minimal

fuel maintains a desired combustion temperature. The heat of combustion is transferred back into the bed, and the agitated mixture of waste, fuel, and hot bed material in the presence of fluidizing air provides an environment that resists fluctuations in temperature and retention time due to moisture, ash, or Btu content of the waste (EPA, 1988). A secondary reaction chamber is usually employed to provide increased retention time for combustion of volatiles. Combustion gases are drawn out of the secondary chamber and treated for removal of acid gas and particulates. The residual materials of the process are decontaminated ash, treated combustion gases, and possibly wet scrubber water. Fluidized beds can operate at lower temperatures due to the high mixing energies aiding the combustion process (EPA, 1988).

Ogden Environmental Services, Circulating Fluidized Bed Combustor (CBC) is an example of this thermal treatment method. Figure 16 shows the CBC process diagram. This technology is currently being demonstrated in the SITE program. It has been applied to two site remediation projects for treating soils contaminated with PCBs and fuel oil (EPA, 1990).

IV-D-1-b. Advantages/Disadvantages

Advantages:

1. Wastes can be combusted at lower temperatures than that of conventional incinerators.
2. Temperatures in the vessel are low enough to prevent formation of significant amounts of NO_x (Lee & Huffman, 1989).

TABLE 7. TECHNOLOGY SUMMARY
WASTE TYPE: Soils and Sludges
TECHNOLOGY: High-Temperature Thermal Treatment - General*

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
High moisture content	Moisture content affects handling and feeding and has major impact on process energy requirements.	Analysis for moisture content
Elevated levels of halogenated organic compounds	Halogens form HCL, HBr, or HF, when thermally treated; acid gases may attack refractory material and/or impact air emissions.	Quantitative analysis for organic Cl, Br, and F
Presence of PCBs, dioxins	PCBs and dioxins are required to be incinerated at higher temperatures and long residence times. Thermal systems may require special permits for incineration of theses wastes.	Analysis for priority pollutant
Presence of metals	Metals (either pure or as oxides, hydroxides, or salts) that volatilize below 2000°F (e.g. As, Hg, Pb, Sn) may vaporize during incineration. These emissions are difficult to remove using conventional air pollution control equipment. (continued)	Analysis for heavy metals

Adapted from the Environmental Protection Agency (EPA, 1988)
* Applicable to fluidized bed, infrared, rotary kiln, wet air oxidation, and pyrolytic as well as vitrification processes.

TABLE 7 continued,

Characteristics Impacting Process Feasibility	Reason for Potential Impact	Data Collection Requirements
	Furthermore, elements cannot be broken down to nonhazardous substances by any treatment method. Therefore, thermal treatment is not useful for sludges with heavy metals as the primary contaminant. Additionally, an element such as trivalent chromium (Cr^{+3}) can be oxidized to a more toxic valence state, hexavalent chromium (Cr^{+6}). in combustion systems with oxidizing atmospheres.	
Elevated levels of organic phosphorus compounds	During combustion processes, organic phosphorus compounds may form phosphoric acid anhydride (P_2O_5), which contributes to refractory attack and slagging problems.	Analysis for phosphorus

Adapted from the Environmental Protection Agency (EPA, 1988)

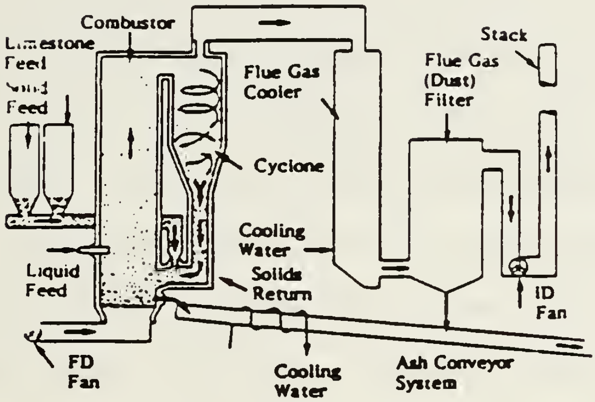
3. The bed material acts as a scrubber to capture acid gas, reportedly creating a non-toxic solid residue.

4. One of only seven incinerators permitted to burn PCBs.

Disadvantages:

1. Disposal of the inert residual bed may be a problem (Lee & Huffman, 1989).

Figure 16. Fluidized Bed Incinerator.
(Circulating Fluidized Bed Combustor)



Adapted from the Environmental Protection Agency, (EPA, 1989)

2. Large amounts of fine particulate matter entrained in exhaust gases may require elaborate pollution control devices.

3. Waste feed particle size must be controlled to maintain a uniform feed rate.

IV-D-1-c. Demonstration/Field Tests results

The CBC technology is one of seven nationwide incinerators permitted to burn PCBs (EPA, 1989). It will be demonstrated early in 1990 at the McColl Superfund site in Fullerton, Ca.

IV-D-1-d. Cost data

$100 - 200 per ton is estimated for a 10,000 ton/yr CBC unit processing oily wastes sludges.

IV-D-2. Rotary kiln incineration

IV-D-2-a. Description and Operation of the Technology

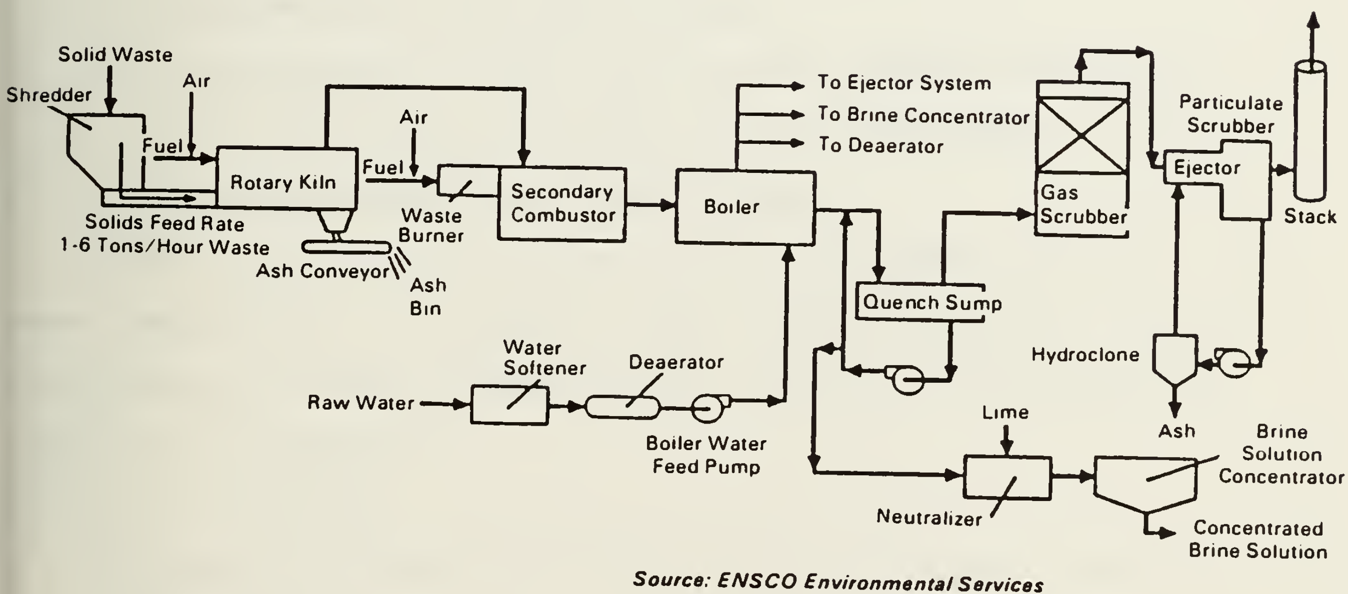
Rotary kiln incinerators are slightly inclined, refractory lined cylinders (Figure 17). Their primary use is the combustion of organic solids and sludges, including RCRA and other contaminated waste. Rotation of the shell enhances mixing of solid wastes while creating turbulence and improving the degree of burnout of the solids. Retention time can vary from several minutes to more than an hour. Wastes and auxiliary fuel are injected into the high end of the kiln and passed through the combustor zone as the kiln slowly rotates. Wastes are substantially oxidized to gases and inert ash within this zone. Ash is removed at the lower end of the kiln. Flue gases are passed through a secondary combustion chamber and then through pollution control equipment to remove particulate and acid gas. Rotary kiln incinerators, both fixed and mobile, are widely available from many vendors and are in broad use for hazardous waste applications (EPA, 1988). Residuals generated from this process include:

- Ash from the low end of the kiln and in some cases from air pollution control devices
- Stack gases
- Brine solution from the ash quench and wet scrubber

Rotary kiln incinerators are available in both fixed and mobile units. This type of incineration device is widely available from a number of vendors. Cement kilns, universally designed as rotary types, have successfully destroyed chlorinated organic compounds in

various countries throughout the world (Potter et al., 1986). Currently, the only new area of innovation on rotary kiln incinerators has been in the area of fuel injection and mixing concepts. Improvements in waste throughput capacities have been shown by adapting existing rotary kiln incinerators using devices such as this.

Figure 17. Rotary Kiln Incinerator



Adapted from Environmental Protection Agency (EPA, 1988)

IV-D-2-b. Advantages/disadvantages

Advantages:

1. Proven as an effective hazardous waste destructive technology for a broad range of contaminants which include solids, liquids, and sludges.
2. Commercially available from a number of vendors in fixed and mobile units.

Disadvantages:

1. Requires additional air pollution emission treatment and monitoring devices.
2. New devices will have to go through licensing procedures, which are costly and require a significant amount of time.

IV-D-2-c. Demonstration/Field Tests results

Rotary kiln devices have been used for a number of years in waste destruction. Currently there are not specific units participating in such programs as SITE due to their existing wide commercial availability.

IV-D-2-d. Cost data

Available information on rotary kiln incinerators indicate that operational costs range up to $600 per ton of waste (Potter et al., 1986).

IV-D-3. Infrared Thermal Treatment.

IV-D-3-a. Description and Operation of the Technology

Infrared thermal units use silicon carbide elements to generate thermal radiation beyond the red end of the visible

spectrum. Materials to be treated are fed through on a belt and are exposed to the radiation. Off-gases pass into a secondary chamber, which can be either a combination gas-fired/infrared unit or a conventional secondary chamber (EPA, 1988). The primary process variables as in most incineration devices are temperature, residence time, and waste layer thickness, and combustion air flow. The normal operating temperatures in the primary chamber are 1400°F and 1600°F in the secondary chamber, though temperatures can be much higher based on type of secondary chamber used. The optimum material thickness is reported to be 2 inches for throughput. Residence times can vary from 5 minutes to 50 minutes. Mobile units are available and have been used to treat hazardous waste under CERCLA. The infrared unit (Figure 18) is a system originally developed by Shirco Infrared Systems of Dallas, Tx. The infrared system is probably the most used thermal innovative technology in both RCRA-waste destruction and Superfund waste remediation (Lee & Huffman, 1989). Residuals from the process are ash, scrubber water, and off gases.

IV-D-3-b. Advantages/disadvantages

Advantages:

1. Has been used extensively for hazardous waste destruction.
2. Available in mobile units for on-site treatment.
3. When compared to other technologies the infrared system has better control over the residence time in the primary combustion chamber (Lee & Huffman, 1989).

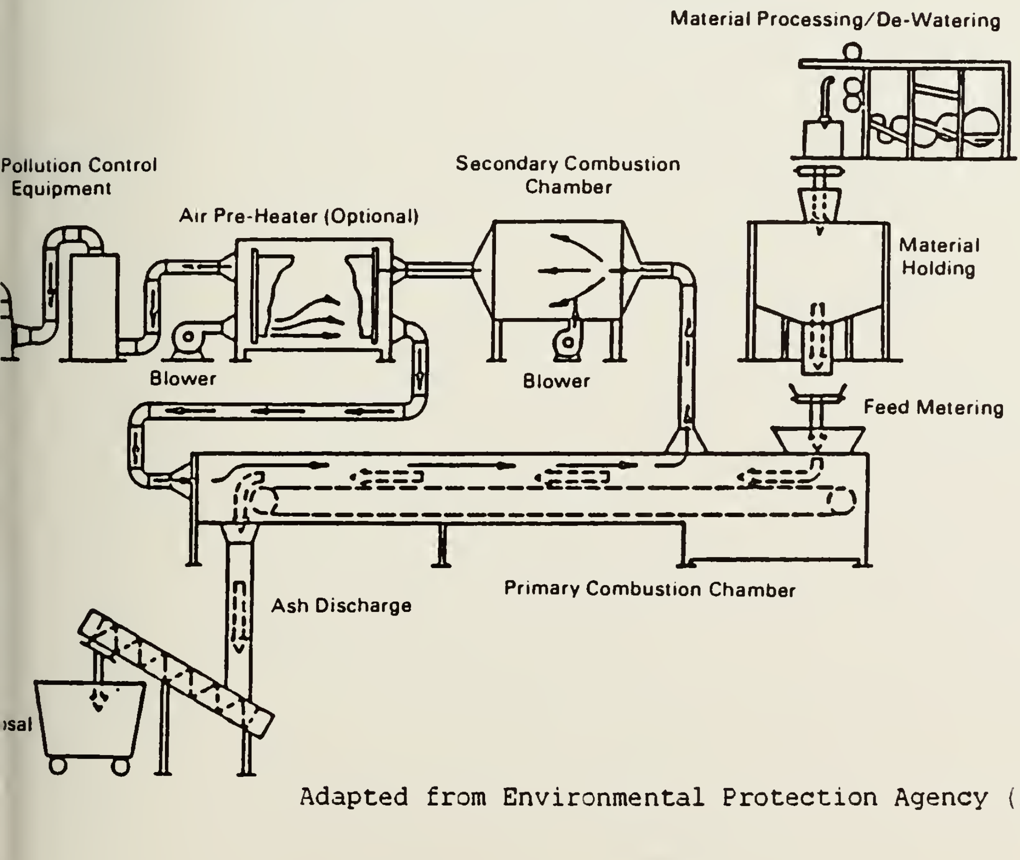
Disadvantages:

1. Pretreatment may be necessary to control waste particle size.
2. Liquid wastes must be mixed with sand, or other solid material in order to be destroyed effectively in the primary combustion chamber.
3. Availability of units may decline as Shirco Infrared Systems is no longer producing units.

IV-D-3-c. Demonstration/Field Tests results

The infrared thermal technology has been used extensively in the treatment of RCRA and Superfund wastes. An evaluation of a full-scale mobile unit was conducted from 1 - 4 August at the Peak

Figure 18. Infrared thermal treatment process



Adapted from Environmental Protection Agency (EPA, 1988)

Oil site, an abandoned oil refinery in Tampa, Fla. Significant results were:

- PCBs were reduced to less than 1 ppm
- DRE standards for air emissions were achieved (greater than 99.99%)
- Lead was not immobilized
- High feed rates and reduced power consumption was achieved by adding fuel oil to the waste feed.

IV-D-3-d. Cost data

A cost range of $180/ton to $240/ton of waste feed excluding waste excavation costs, feed preparation, profit, and ash disposal cost was estimated. Overall costs may go as high as $800/ton.

CONCLUSIONS

1. Current disposal methods are available, or are being developed that can dispose of oily wastes in accordance with the more stringent environmental regulations.
2. The Navy currently relies almost entirely on contractor disposal for oily waste sludges from fuel facilities. While this method has proven to be cost effective in the short run, the liability issues surfacing due to more stringent environmental regulations may require evaluation over the long term.
3. Disposal costs should be anticipated to increase over the next five years, due to the effect of the "land bans" and more stringent environmental regulations imposed on other disposal methods. Analyses of future disposal options should reflect this trend, as well as benefits of on-site disposal in relation to liability issues .
4. Current and proposed innovative treatment technologies do not provide a truly "ultimate" disposal method. Each process produces residues requiring further disposal or treatment prior to disposal. Processes must be evaluated based on the particular waste streams requiring disposal. Certain methods can react with various constituents in wastes to form more toxic wastes or residue.

5. EPA's future regulations will focus on waste minimization, as well as the addition of constituents to the hazardous material list, based upon a conversation with Mr. Gary Bertram of EPA Region VII (personal communication, April 17, 1990). Fuel facilities should include hazardous waste disposal, waste minimization, and environmental goals in Activity Strategic Plans.

6. Biodegradation may offer a viable waste disposal method based on available facilities and local/state environmental regulations. Old tank berms, which limit groundwater contamination could be adapted to provide a "solid-phase" biodegradation system. Biodegradation systems are not a choice of SITE projects in many cases, due to the requirement to clean up hazardous waste sites in a short period of time.

7. The Navy Civil Engineering Laboratory has conducted numerous evaluations of Navy oily wastes. At least one study has been performed on Oily Sludge Treatment Technologies (deMonsabert, 1984). NCEL should be routinely queried to determine their ongoing research in this particular area.

8. Hazardous waste statistics for fuel facilities are not currently accumulated. Data could be of use to determine the extent of Navy Fuel facility problems and to support future capital justifications.

VI. RECOMMENDATIONS

I recommend the Navy evaluate hazardous waste disposal options based on long-term cost/benefit basis.

I recommend that Fuel Terminal Directors develop an awareness of the current hazardous wastes disposal methods being employed by contractor's servicing the facility.

I recommend a further evaluation of those technologies that can provide on-site disposal. Capital costs of equipment, required permitting costs, and personnel requirements, should be compared to future disposal costs, liability considerations, as well as improved operational flexibility, and long-term payback.

I recommend waste reduction processes, some currently in use such as filter presses, be evaluated to determine their ability to reduce waste quantities requiring disposal.

I recommend innovative technologies be evaluated whenever possible on Navy oily wastes in conjunction with environmental and research facilities.

I recommend that hazardous waste data be included on annual fuel facility reports in order to accumulate Navy-wide Fuel facility hazardous waste information.

California Wastes - a group of liquid hazardous wastes, including ones with PCB's, heavy metals, and halogenated organic compounds the EPA was required to evaluate by July 8, 1987 to determine if they should be banned from land disposal or if restrictions should be placed on the land disposal of these wastes. Wastes were determined hazardous and restricted from land disposal.

DAF (Dissolved Aeration Flotators) Scum Sludges - contains, in addition to separated oil, substantial amounts of chemicals, both organic and inorganic, added during process. Est. to contain only 2% oil. (NAVFAC P-916, 1985)

delisting - a process whereby a type of waste that is listed as hazardous by EPA can be excluded from hazardous waste regulation. If the generator can demonstrate that a particular waste does not pose risks to human health and the environment, the waste can be delisted.

DRE (Destruction and Removal Efficiency) - 99.99% under RCRA

dscf (dry standard cubic feet)

dscfm (dry standard cubic feet per minute)

dscm (dry standard cubic meters)

dscmm (dry standard cubic meters per minute)

EPA Identification Number - the unique number assigned by EPA to each generator or transporter of hazardous waste, and each treatment, storage, or disposal facility. (EPA, 1986)

EP Toxicity - a test, extraction procedure, designed to identify waste likely to leach hazardous concentrations of particular toxic constituents into the ground water as a result of improper management. A characteristic of a hazardous waste. (EPA, 1986)

Exception Report - a report that generators who transport waste off-site must submit to the Regional Administrator if they do not receive a copy of the manifest signed and dated by the owner or operator of the designated facility where their waste was shipped within 45 days from the date the initial transporter accepted the waste. (EPA, 1986)

Freeboard - the vertical distance between the top of a tank or surface impoundment dike, and the surface of the waste contained therein. (EPA, 1986)

Free liquids - liquids which readily separate from the solid portion of a waste under ambient temperature and pressure.

Fuel Tank Sludges - probably the single, largest source of oily sludges produced by the Navy. They range in composition from watery residues at the bottom of tanks, to heavily emulsified viscous liquid sludges. Watery sludges found in tanks normally contain small amounts of free and dissolved oil, PAH's, phenols, and heavy metals. Black and viscous sludges found in fuel tanks may contain as much as 80% free oil, 40,000 ppm PAH's, and 1,000 ppm phenols. (NAVFAC P-916, 1985)

Generator - any person, by site, whose act or process produces hazardous waste identified or listed in CFR40 Part 261, or whose act first causes a hazardous waste to become subject to regulation. (EPA, 1986)

Hammer Provision - Statuatory requirements that go into effect automatically if EPA fails to issue regulations by certain dates specified in the statute. (EPA, 1986)

Hazardous and Solid Waste Amendments of 1984 (HSWA) - (Public Law 98-616) significantly expanded both the scope and the coverage of RCRA. (EPA, 1986)

Incinerator - any enclosed device using controlled flame combustion that neither meets the criteria for classification as a boiler nor is listed as an industrial furnace. (EPA, 1986)

In situ Treatment Technology - a technology that can be applied to treat the hazardous constituents of a waste or contaminated environmental medium where they are located and is capable of reducing the risk posed by these constituents to an acceptable level or completely eliminating that risk. (EPA, 1990)

Landfill - a disposal facility or part of a facility where hazardous waste is placed in or on land and which is not a pile, a land treatment facility, a surface impoundment, an underground injection well, a salt dome formation, a salt bed formation, an underground mine, or a cave.

Landfill cell - a discrete volume of a hazardous waste landfill which uses a liner to provide isolation of wastes from adjacent cells or wastes. Examples of landfill cells are trenches and pits.

Land treatment facility - a facility or part of a facility at which hazardous waste is applied onto or incorporated into the soil surface; such facilities are disposal facilities if the waste will remain after closure.

Leachate - any liquid, including any suspended components in the liquid, that has percolated through or drained from the hazardous waste.

Listed - hazardous wastes that have been placed on one of three lists developed by EPA: Non-specific source waste, Specific source wastes; Commercial chemical products. (EPA, 1986)

Part A Permit - first part of the two part application that must be submitted by a TSD facility to receive a permit. The document contains general facility information. (EPA, 1986)

Part B Permit - the second part of the permit application that includes detailed and highly technical information concerning the TSD in question. (EPA, 1986)

Permit - an authorization, license, or equivalent control document issued by EPA or an authorized State to implement the regulatory requirements of Subtitle C Parts 264 and 265 for TSDs. (EPA, 1986)

Permit-By-Rule - a provision of Subtitle C whereby a facility is deemed to have a RCRA permit if it is permitted under the Safe Drinking Water Act, the Clean Water Act, or the Marine Protection, Research, and Sanctuaries Act and also meets a few additional Subtitle C requirements as specified at 40 CFR Section 270.60. (EPA, 1986)

Pile - any non-containerized accumulation of solid, nonflowing hazardous waste that is used for treatment or storage.

PCB (Polychlorinated biphenyls) - applicable regulatory standard is 99.9999% under the TSCA.

Polynuclear Aromatic Hydrocarbons (PAH's) - class of organic compounds that are usually characterized by the presence of two or more fused aromatic rings. Some of these compounds have been identified as carcinogens while others are suspected carcinogens. The state of California classifies 13 pahs as hazardous substances. (NAVFAC P-916, 1985)

Primary Treatment Sludges - sludges separated by gravity only. Separation takes place in oil sumps, oily waste storage tanks, and gravity separators. High in free oil content,(approx. 20%), significant amounts of inorganic (approx. 5%), and organic solids (approx. 3-5%) and smaller concentrations of dissolved oil (approx. 1%). Concentration of toxic chemical compounds present in sludges is high: polynuclear aromatic hydrocarbons, approx. 6000 ppm, phenols

approx. 500 ppm, and heavy metals approx. 400 ppm. As a rule toxicity of these sludges is quite high and similar to that of phenol. (NAVFAC P-916, 1985)

POHC (Principal organic hazardous constituent) - Specific hazardous compounds monitored during an incinerator's trial burn. POHCs are selected based on their high concentration in the waste feed and their difficulty to burn relative to other organic compounds contained in the waste. For each waste feed, one or more POHCs may be designated.

PIC (Product of incomplete combustion) - organic compounds formed when combustion occurs. These compounds are generated in very small amounts and are sometimes toxic.

POTW (Publicly owned treatment works)

RCRA (Resource Conservation and Recovery Act) - an amendment to the Solid Waste Disposal Act, was passed in 1976 to address the problem of the disposal of municipal and industrial solid waste. Goals are to:

a. Protect human health and the environment
b. to reduce waste and conserve energy and natural resources
c. To reduce or eliminate the generation of hazardous waste as expeditiously as possible.
(EPA, 1986)

Secondary Treatment Sludges - are produced in DAF, API, and coalescer separators. These processes are used mainly at the major and intermediate size treatment facilities to treat effluent from primary separation unit-processes prior to discharge into natural receiving bodies of water. Sludges are generally low in free oil (approx. 2%), dissolved oil (approx. 1%), and toxic chemical compounds: PAH's, (approx. 300 ppm), phenols (300 ppm), and heavy metals (approx. 150 ppm). The sludges contain a fair amount of inorganic (approx. 2%) and organic (approx. 4%) solids. (NAVFAC P-916, 1985)

Sludge - (CFR40, 260.10) any solid, semi-solid or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility exclusive of the treated effluent from a wastewater treatment plant.

Storage - the holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere.

Surface impoundment - a facility or part of a facility which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although

it may be lined with man-made materials), which is designed to hold an accumulation of liquid wastes or wastes containing free liquids, and which is not an injection well. Examples of surface impoundments are holding, storage, settling and aeration pits, ponds, and lagoons.

Thermal treatment - the treatment of hazardous waste in a device which uses elevated temperatures as the primary means to change the chemical, physical, or biological character or composition of the waste. Examples of thermal treatment processes are incineration, molten salt, pyrolysis, calcination, wet air oxidation, and microwave discharge.

TSCA (Toxic Substances and Control Act) - the federal statute under which the incineration of PCBs is regulated.

Treatment - any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

Treatment zone - a soil area of the unsaturated zone of a land treatment unit within which hazardous constituents are degraded, transformed, or immobilized.

Unsaturated zone (zone of aeration) - the zone between the land surface and the water table.

<u>APPENDIX</u>

Waste Technology Matrix: Sludges

Contaminant / Table	A.1-1 Fluidized bed incineration	A.2-1 Rotary kiln incineration	A.3-1 Infrared thermal treatment	A.4-1 Wet air oxidation	A.5-1 Pyrolysis-incineration	A.6-1 Vitrification	B.1-1 Chemical extraction	B.2-1 In situ chemical treatment	B.5-1 Glycolate dechlorination	B.8-1 Stabilization/solidification	B.9-1 Chemical reduction oxidation	B.10-1 In situ vitrification	C.1-1 Biodegradation	C.2-1 In situ biodegradation
Organic														
Halogenated volatiles	◒	●	●	◒	◒	◒	◒	○	◒	◒	◒	◒	◒	◒
Halogenated semivolatiles	◒	●	●	◒	◒	◒	●	○	◒	◒	◒	◒	◒	◒
Nonhalogenated volatiles	◒	●	●	◒	◒	◒	◒	○	○	◒	◒	◒	◒	◒
Nonhalogenated semivolatiles	◒	●	●	◒	◒	◒	●	○	○	◒	◒	◒	◒	◒
PCBs	◒	●	●	◒	◒	◒	●	○	◒	◒	◒	◒	◒	◒
Pesticides	◒	●	◒	◒	◒	◒	◒	○	◒	◒	◒	◒	◒	◒
Organic cyanide	◒	●	◒	◒	◒	◒	◒	◒	○	◒	●	◒	◒	◒
Organic corrosives	◒	●	◒	◒	◒	◒	◒	◒	○	◒	○	◒	X	X
Inorganic														
Volatile metals	X	X	X	○	○	X	○	○	○	●	◒	◒	X	X
Nonvolatile metals	○	○	○	○	○	◒	○	○	○	●	◒	◒	X	X
Asbestos	○	○	○	○	◒	●	○	○	○	●	○	◒	○	○
Radioactive materials	○	○	○	○	○	◒	○	○	○	●	○	●	X	X
Inorganic corrosives	○	○	○	◒	◒	◒	○	◒	○	●	○	◒	X	X
Inorganic cyanides	◒	◒	◒	◒	◒	◒	○	◒	○	●	●	◒	X	X
Reactive														
Oxidizers	◒	◒	◒	○	◒	◒	X	◒	○	◒	◒	◒	X	X
Reducers	◒	◒	◒	◒	◒	◒	X	◒	○	◒	◒	◒	X	X

- ● Demonstrated effectiveness
- ◒ Potential effectiveness
- ○ No effectiveness
- X Potential adverse impacts to process or environment

* Do not use this matrix table alone. Please refer to the cited appendices for guidance.

Adapted from the Environmental Protection Agency (EPA, 1988)

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c.1 A review and recommendations of the most promising technologies for treating sludges resulting from the oil waste treatment process.